



Industria y Comercio

SUPERINTENDENCIA

PCT

DELEGATURA PROPIEDAD INDUSTRIAL

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO
INVENTARIO

NOV 2

SOLICITUD
REGISTRO DE PATENTE DE INVENCION
PCT

EXPEDIENTE No

11-134831

TITULO SISTEMA Y MÉTODO PARA AJUSTAR
DINÁMICAMENTE EN CENTRO DE GRAVEDAD DE
UN APARATO DE PERFORACIÓN

CLASIFICACION INTERNACIONAL _____

SOLICITANTE HALLIBURTON ENERGY SERVICES,
INC

DOMICILIO Texas, Estados Unidos de América

APODERADO DARIO CARDENAS NAVAS

BOGOTA D.C. _____

13-10-2011
No

PETITORIO



SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO



No. 11-134831- -00000-0000

Fecha: 2011-10-11 15:04:57 Dep. 2020 DIR.NUEVASCR
Tra. 11 PATENTEIYII Eje: 378 FASENACIONALI
Act. 411 PRESENTACION Folios: 113

FORMULARIO UNICO DE SOLICITUD DE PATENTE PCT ENTRADA EN FASE NACIONAL

①

SOLICITUD DE:



Patente de Invención



Patente de Modelo de Utilidad



Capítulo I



Capítulo II

②

SOLICITANTE

Nombre: **HALLIBURTON ENERGY SERVICES, INC**

Dirección: 2601 Beltline Road, Carrollton, Texas 75006, Estados Unidos de América

Nacionalidad o Domicilio: Texas, Estados Unidos de América

Lugar de Constitución: Estados Unidos de América

Teléfono: 3137800 Fax: 3122410

E-mail: general@cardenasycardenas.com

IDENTIFICACION



NIT



NIT



Otro



Otro

Cuál
Número

③

REPRESENTANTE
O APODERADO

Nombre: **LUZ HELENA ADARVE GOMEZ**

Dirección: Carrera 7 No 71-52 Torre B Piso 9

Teléfono: 313 7800 Fax: 312 3600

E-Mail: general@cardenasycardenas.com

IDENTIFICACION



NIT



NIT



Otro



Otro

Cual
Número 41575435 TP 14884
BTA C.S.J.

④

INVENTOR(ES)
(72)

Nombre: 1. John H. Hales
2. Allison E. Novak
3. John D. Burleson

Dirección: 1. 2601 Beltline Road, Carrollton, TX 75006, Estados Unidos de América
2. 2601 Beltline Road, Carrollton, TX 75006, Estados Unidos de América
3. 2601 Beltline Road, Carrollton, TX 75006, Estados Unidos de América

Nacionalidad o Domicilio: 1. Norteamericano
2. Norteamericano
3. Norteamericano

⑤ PCT (86)

Solicitud Internacional No. WO 2010/104634 A1 Fecha 16.09.2010
Publicación Internacional No. PCT/US2010/023545 Fecha 09.02.2010

⑥

Título(54): **SISTEMA Y MÉTODO PARA AJUSTAR DINÁMICAMENTE EL CENTRO DE GRAVEDAD DE UN APARATO DE PERFORACIÓN**

⑦

Clasificación Internacional (51): E21B43/119 - E21B43/116 - E21B43/117

⑧

Prioridad

(33)País de Origen

(32)Fecha

(31)N° de Solicitud

SI ☒ NO ☐

US

13.03.2009

12/403,420

⑨

Comprobante de Pago No.: 11-0099488

Fecha 11.10.2011

Revisión
2011-10-13
10630

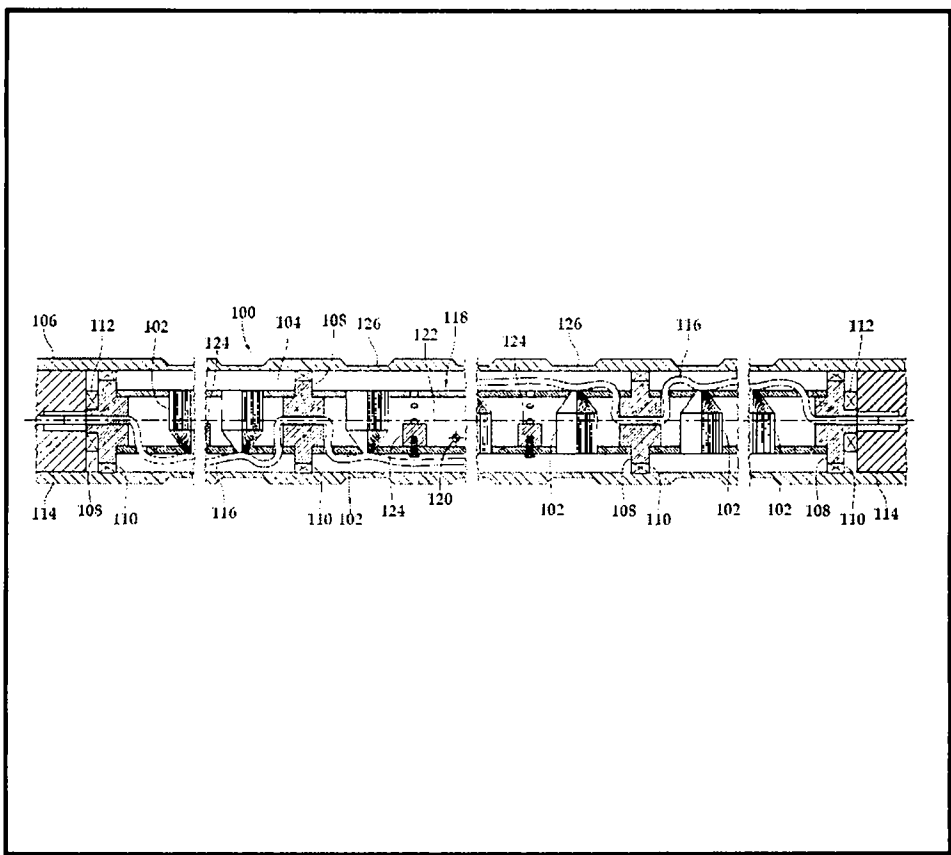
10 ANEXOS

- ☒ Comprobante de pago de la tasa de presentación de la solicitud.
- ☒ Documento que acredita la existencia y representación legal cuando el solicitante sea persona jurídica.
- ☒ Poderes, si fuere el caso.
- ☐ Documento de cesión del inventor al solicitante o a su causante.
- ☒ Traducción de la solicitud internacional al castellano (Resumen, Resumen, descripción, reivindicaciones, dibujos)
- ☐ Copia del examen preliminar internacional efectuado por la Autoridad Internacional de Examen Preliminar (IPEA)
- ☐ Traducción del examen preliminar internacional efectuado por la IPEA.
- ☐ De ser el caso, copia del contrato de acceso.
- ☐ De ser el caso, documento que acredite la licencia o autorización de uso de conocimientos tradicionales de las comunidades indígenas.
- ☐ De ser el caso, certificado de depósito del material biológico.
- ☒ Arte final 12x12.
- ☐ De ser el caso, información sobre otras solicitudes de patente o títulos obtenidos en el extranjero por el mismo titular o su causante, relacionadas parcial o totalmente con la invención de esta solicitud.
- ☐ Recibo Reivindicaciones adicionales
- ☒

Prioridad

<http://www.wipo.int/patentscope/search/en/detail.jsf;jsessionid=99C5A7200290901ADFB5B0557E013257.wapp1?docId=WO2010104634&recNum=1&tab=PCTDocuments&maxRec=&office=&prevFilter=&sortOption=&queryString=>

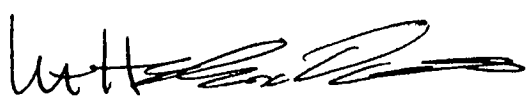
11 FIGURA CARACTERISTICA



12

Solicito la Concesión de la patente

NOMBRE: LUZ HELENA ADARVE GOMEZ

FIRMA: 
 JAG C.C. 41575435 BTA TP. 14884 CSJ

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

DIVISION DE NUEVAS CREACIONES

TARJETA ARCHIVO PROPIETARIOS

PATENTE DE INVENCION ____ PCT X MODELO DE UTILIDAD ____ DISEÑO INDUSTRIAL ____



Industria y Comercio

SUPERINTENDENCIA

(21) N° de solicitud:

(22) Fecha de solicitud:

(51) Clasificación Internacional :

(71) Solicitante(s) **HALLIBURTON ENERGY SERVICES, INC**

(72) Inventor(es) **Jhon H. Hales, Allison E. Novak, John D. Burleson**

(74) Apoderado: **LUZ HELENA ADARVE GOMEZ**

(30) Prioridad	(31) <i>No. Prioridad</i>	(32) <i>Fecha</i>	(33) <i>País</i>
	12/403,420	13.03.2009	US

(85) Fecha inicio fase nacional: 13.10.2011

(86) Datos relativos a la presentación de la solicitud PCT

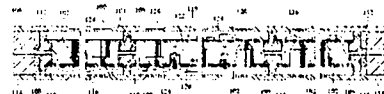
Fecha de presentación de la solicitud: 09.02.2010

No. de solicitud **PCT/US2010/023545**

(54) Título **SISTEMA Y MÉTODO PARA AJUSTAR DINÁMICAMENTE EL CENTRO DE GRAVEDAD DE UN APARATO DE PERFORACIÓN**

**SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO****DIVISION DE NUEVAS CREACIONES****TARJETA ARCHIVO TEMATICO****Industria y Comercio**SUPERINTENDENCIA PATENTE DE INVENCION ____ PCT X MODELO DE UTILIDAD ____ DISEÑO INDUSTRIAL

(21) N° de solicitud:		(22) Fecha de solicitud:	
(51) Clasificación Internacional:			
(71) Solicitante(s) HALLIBURTON ENERGY SERVICES, INC			
(72) Inventor(es) Jhon H. Hales, Allison E. Novak, John D. Burleson			
(74) Apoderado: LUZ HELENA ADARVE GOMEZ			
(30) Prioridad	(31) No. Prioridad 12/403,420	(32) Fecha 13.03.2009	(33) País US
(85) Fecha límite inicio fase nacional: 13.10.2011		(87) Publicación internacional:	
(86) Datos relativos a la presentación de la solíc. PCT Fecha de presentación de la solicitud: 09.02.2010 No. de solicitud PCT/US2010/023545		Fecha: 16.09.2010 No. Publicación WO2010/104634 A1	

**(54) Título: SISTEMA Y MÉTODO PARA AJUSTAR DINÁMICAMENTE EL CENTRO DE GRAVEDAD DE UN APARATO DE PERFORACIÓN****(57) Resumen:**

Un aparato de perforación (100) usado para perforar un pozo subterráneo. El aparato de perforación (100) incluye un portador de pistola generalmente tubular (106) que tiene un sostenedor de carga (104) montado de manera rotatable dentro del portador de pistola (106). Al menos una carga hueca (102) se monta en el sostenedor de carga (104) y es operable para perforar el pozo durante la detonación. Un sistema de peso dinámicamente ajustable (124) se asocia de manera operable al sostenedor de carga (104). El sistema de peso dinámicamente ajustable (124) es operable para ajustar el centro de gravedad (120) del sostenedor de carga (104) de manera que la gravedad provocará que el sostenedor de carga (104) rote dentro del portador de pistola (106) para posicionar al menos una carga hueca (102) en una dirección circunferencial deseada en relación con el pozo previo a la perforación.



(21) N° de solicitud:	(51) Int Cl:
22) Fecha de solicitud:	(71) Solicitante(s) HALLIBURTON ENERGY SERVICES, INC
(30) Prioridad (31) No. Priodidad 32) Fecha (33) País 12/403,420 13.03.2009 US	(72) Inventor(es) Jhon H. Hales, Allison E. Novak, John D. Burleson
	(74) Apoderado: LUZ HELENA ADARVE GOMEZ
(54) Título: SISTEMA Y MÉTODO PARA AJUSTAR DINÁMICAMENTE EL CENTRO DE GRAVEDAD DE UN APARATO DE PERFORACIÓN	

Un aparato de perforación (100) usado para perforar un pozo subterráneo. El aparato de perforación (100) incluye un portador de pistola generalmente tubular (106) que tiene un sostenedor de carga (104) montado de manera rotatable dentro del portador de pistola (106). Al menos una carga hueca (102) se monta en el sostenedor de carga (104) y es operable para perforar el pozo durante la detonación. Un sistema de peso dinámicamente ajustable (124) se asocia de manera operable al sostenedor de carga (104). El sistema de peso dinámicamente ajustable (124) es operable para ajustar el centro de gravedad (120) del sostenedor de carga (104) de manera que la gravedad provocará que el sostenedor de carga (104) rote dentro del portador de pistola (106) para posicionar al menos una carga hueca (102) en una dirección circunferencial deseada en relación con el pozo previo a la perforación.

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

NIT : 800.176.089-2

- / -



Industria y Comercio
SUPERINTENDENCIA

RECIBO DE CAJA

No. 11 - 0099488

Bogotá D.C., Octubre 10 de 2011 - 15:04:00

RECIBIDO DE : CARDENAS & CARDENAS ABOGADOS PI LTDA

NI 830.083.491

*** Soporte del Pago ***

TIPO PAGO	BANCO	CUENTA	No. PAGO	FECHA PAGO	VR. PAGO
CONSIGNACION	BANCO DE BOGOTA	062754387	186851383	10/10/2011	14.910.400.00

*** Conceptos Pagados ***

CANT.	RENTISTICO	CONCEPTO	Vr.UNDITARIO	Vr.CONCEPTO
1	50005-01-01 SOLICITUDES	1 TRAMITES DE SOL. DE PATENTE DE INVENCIÓN	571.000.00	571.000.00
				<u>\$571.000.00</u>
=====				

SON: **QUINIENTOS SETENTA Y UN MIL PESOS MONEDA CORRIENTE**

Responsable: _____

Recibo de Caja Aplicado al Expediente No. _____

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO



No. 11-134831- -00000-0000

Fecha: 2011-10-11 15:04:57 Dep. 2020 DIR.NUEVASCR
Tra. 11 PATENTEIYII Eve: 378 FASENACIONALI
Act. 411 PRESENTACION Folios: 113

CARDENAS & CARDENAS

ABOGADOS

Sede Centro: Carrera 13 No. 27 - 00 Pisos 3,4,5 y 10 Bogotá, D.C.- Colombia

Web: www.sic.gov.co e-mai: info@sic.gov.co Conmutador: (571) 5870000 Fax: (571) 5870284 Línea: 018000-910165 Call Center: (571) 6513240

Octubre 10 de 2011 - 15:04:05



The State of Texas

Secretary of State

000914

Requested for use in COLOMBIA

Not for use within the United States of America

This Apostille only certifies the signature, the capacity of the signer and the seal or stamp it bears. It does not certify the content of the document for which it was issued.

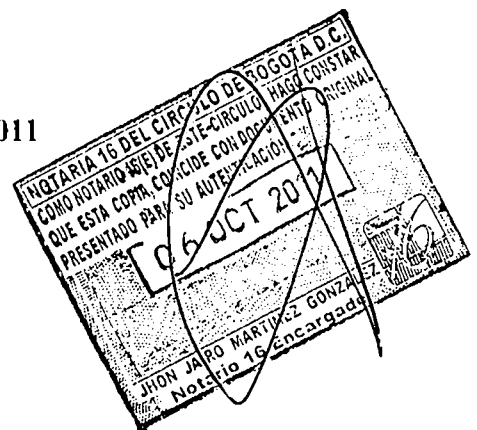
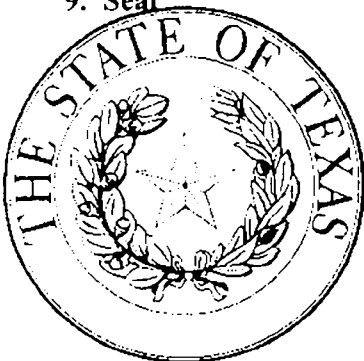
APOSTILLE

(Convention de La Haye du 5 Octobre 1961)

- | | |
|--------------------------------|--|
| 1. Country | United States of America |
| This public document | |
| 2. has been signed by | VALORIE CASEY |
| 3. acting in the capacity of | Notary Public, State of Texas |
| 4. and bears the seal/stamp of | VALORIE CASEY,
Notary Public, State of Texas,
Commission Expires: 10-16-14 |

CERTIFIED

- | | |
|---------------------------------------|--------------------|
| 5. at Austin, Texas | 6. on June 9, 2011 |
| 7. by the Secretary of State of Texas | |
| 8. Certificate No. N-802693 | |
| 9. Seal | 10. Signature: |



Hope Andrade

Hope Andrade
Secretary of State

ST/cg

- Colombia -

POWER OF ATTORNEY

In the city of Houston, Texas on the 31st day of the month of May, two thousand and eleven (2011) before me, Valorie Casey Notary Public, appeared James W. Ferguson of age, and domiciled at Houston, Texas, and stated:

FIRST: That he/she acts in his/her capacity of Senior Vice President & Deputy General Counsel of **HALLIBURTON ENERGY SERVICES, INC.**, legally constituted and in existence in accordance with the laws of the State of Delaware, United States of America and domiciled at 2601 Beltline Road, Carrollton, Texas 75006, United States of America, as evidenced in the documents which I have examined.

SECOND: That in such capacity he/she grants hereby special, ample and sufficient Power of Attorney to DARIO CARDENAS-NAVAS and/or LUZ HELENA ADARVE-GOMEZ and/or EDUARDO CARDENAS-CABALLERO and/or BERNARDO P. CARDENAS-MARTINEZ and/or JUANITA ACOSTA GOMEZ and/or JULY GALINDO QUINTERO, registered lawyers of the firm CARDENAS & CARDENAS-LAWYERS, domiciled at Carrera 7 No. 71-52, Torre B, Piso 9 Bogotá, D.C., Colombia, to carry before the corresponding Colombian national Offices and authorities the proceedings to obtain trademarks, patents, utility models, industrial drawings and designs, deposits of commercial names and ensigns, as well as processing of renewals, assignments, change of name or domicile of the owner, waivers and licenses of the same for which purpose they are empowered to take before said authorities all necessary actions for the indicated purposes; to file applications, statements, claims, formulate descriptions, amendments, oppositions and appeals; pay all taxes and installments and make any other payments determined by law; to receive every document and values issuing the respective discharge; to fulfill any other requirements and take, in general, every measure that they shall deem opportune for the defense and protection of the Industrial Property of the company in the event of infringements, oppositions, proceedings for cancellation or annulment, imposition of fines, passing the antecedents to the courts; they are empowered to appear as plaintiff or defendant before the competent judges, being entitled to transact, submit to arbitration, waive, receive, resign, withdraw, appeal and all other legal powers which may be necessary, and it is hereby declared ever since now valid and good whatever such attorneys do for its benefit, granting them also power to substitute this proxy and if necessary to revoke such substitutions.

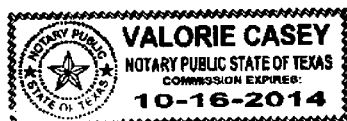
THIRD: That for purposes of articles 597 and 543 of the Colombian code of Commerce the attorneys are empowered to receive service of notice and designate judicial and extrajudicial attorneys.

SIGNED AT Houston, Texas ON May 31, 2011

BY James W. Ferguson

Valorie Casey
NOTARY PUBLIC (Signature)

(Apostille is required)



The undersigned Notary Public certifies that Mr. James W. Ferguson appeared before me and signed the preceding document; that I know him personally and I am certain that he has legal capacity to grant it; that he is Senior Vice President & Deputy General Counsel of **HALLIBURTON ENERGY SERVICES, INC.**, and is consequently authorized to grant such document; that the company is organized under the laws of the State of Delaware, United States of America, and is domiciled 2601 Beltline Road, Carrollton, Texas 75006, United States of America; and that the act for which this document is granted is included among those which constitute the corporate object of said company.

I am certain of all these facts because I have examined the respective documents consisting of certificate of good standing, certificate of incumbency and bylaws of the company all of which I hereby attest.

Valorie Casey

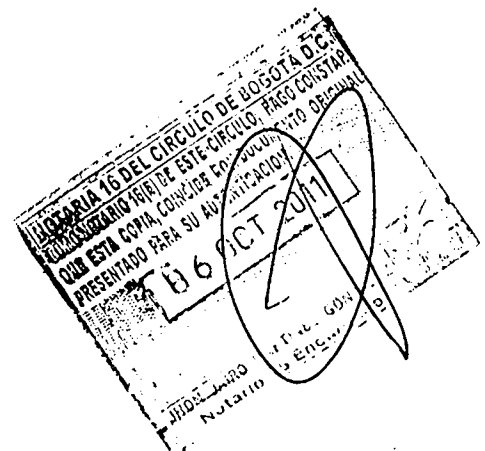
NOTARY PUBLIC (signature)

Issued and signed in Houston, Texas

Dated 5/31/2011



(Apostille is required)



Martha S. Sarmiento S.

MARTHA SOFÍA SARMIENTO SOLANO - TRADUCTORA OFICIAL
Carrera 11D # 124 - 51 Apto. 609 Int. 2 - (571) 2139034 Bogotá - Colombia
E-mail: mssarmiento2@yahoo.com

Martha S. Sarmiento S.

Traductora Oficial Juramentada
Resolución No. 835 Minjusticia

TRADUCCIÓN OFICIAL DE LOS SIGUIENTES DOCUMENTOS: APOSTILLA DE LA CONVENCIÓN DE LA HAYA No. N-802693, con fecha del 9 de Junio de 2011, firmada por Hope Andrade - Secretario de Estado. PODER DE ABOGADO otorgado por la Compañía Halliburton Energy Services, Inc., a la Firma de Abogados Cárdenas y Cárdenas, de Bogotá, Colombia, firmado por James W. Ferguson - Vicepresidente Principal y Asesor Legal General Adjunto de dicha compañía, ante Valorie Casey, Notario Público del Estado de Texas, con fecha del 31 de mayo de 2011. CERTIFICACIÓN NOTARIAL expedida y firmada por Valorie Casey, Notario Público del Estado de Texas, con fecha del 31 de mayo de 2011.

Traducción realizada por Martha Sofía Sarmiento Solano, Traductora e intérprete oficial español - inglés - español, nombrada para el cargo mediante Resolución del Ministerio de Justicia, nº 835, del 3 de mayo de 1988.



ESTADO DE TEXAS

SECRETARIO DE ESTADO



Solicitada para uso en COLOMBIA.

No se debe utilizar en los Estados Unidos de América

Esta Apostilla solamente certificar la firma del funcionario, el cargo y el sello o la estampilla que aparecen en el documento. No certifica el contenido del documento para el cual fue emitida.

APOSTILLA

(Convención de La Haya, 5 de octubre de 1961)

1. País: **Estados Unidos de América**
2. El presente documento público
ha sido firmado por: **VALORIE CASEY**
3. actuando en calidad de: **Notario Público, Estado de Texas**
4. Lleva el sello/ Timbre de: **VALORIE CASEY**
Notario Público, Estado de Texas
Mi Comisión Finaliza el 10-16-14

MARTHA SOFÍA SARMIENTO SOLANO - TRADUCTORA OFICIAL
Carrera 11D # 124 - 51 Apto. 609 Int. 2 - (571) 2139034 Bogotá - Colombia
E-mail: mssarmiento2@yahoo.com

Martha S. Sarmiento S.
Martha S. Sarmiento S.

Traductora Oficial Juramentada
Resolución No. 835 Minjusticia

CERTIFICADO

5. En: **Austin, Texas**
6. El: **9 de junio de 2011**
7. Por: **Secretario de Estado del Estado de Texas**
8. Certificado Número: **N-802693**
9. Lleva Sello /Timbre: **Del Estado de Texas**
10. Firmado por: **Firma Autógrafa**
Hope Andrade
Secretario de Estado

ST/eg



MINISTERIO DE
RELACIONES EXTERIORES
JUL 18 4 00 01
08/06/2011
Martha Sarmiento

MARTHA SOFÍA SARMIENTO SOLANO - TRADUCTORA OFICIAL
Carrera 11D # 124 - 51 Apto. 609 Int. 2 - (571) 2139034 Bogotá - Colombia
E-mail: mssarmiento2@yahoo.com

Martha S. Sarmiento S.
Martha S. Sarmiento S.

Traductora Oficial Juramentada
Resolución No. 835 Minjusticia

- Colombia -

PODER DE ABOGADO

En la ciudad de Houston, Texas, a los 31 días del mes de mayo del año dos mil once (2011), ante mí, Valorie Casey Notario Público, compareció James W. Fergusont, mayor de edad y con domicilio en Houston, Texas, quien declaró lo siguiente:

PRIMERO: Que él actúa, en su calidad de Vicepresidente Principal y Asesor Legal General Adjunto de **HALLIBURTON ENERGY SERVICES, INC.**, una Compañía legalmente constituida y en existencia de conformidad con las leyes del Estado de Delaware, Estados Unidos de América y cuyo domicilio se encuentra ubicado en el 2601 Beltline Road, Carrollton, Texas 75006, Estados Unidos de América, de acuerdo con lo que se evidencia en los documentos que he examinado.

SEGUNDO: Que haciendo uso de las facultades del cargo arriba mencionado, ~~ella~~ otorga Poder de Abogado, especial, amplio y suficiente a **DARÍO GARDENAS NAVAS**, y/o a **LUZ HELENA ADARVE GÓMEZ**, y/o a **EDUARDO GARDENAS CABALLERO**, y/o a **BERNARDO P. CÁRDENAS MARTÍNEZ**, y/o a **JUANITA ACOSTA GÓMEZ**, y/o a **JULY GALINDO QUINTERO**, abogados registrados, quienes trabajan para la firma **CÁRDENAS & CÁRDENAS ABOGADOS**, con sede en la Carrera 7 No. 71-52, Torre B, Piso 9, en Bogotá, D.C., Colombia, para que gestionen en Colombia ante las Oficinas y Autoridades correspondientes la obtención de registros de marcas comerciales, patentes, modelos de utilidad, diseños y dibujos industriales, depósitos de nombres y enseñas comerciales, como también para el procesamiento de renovaciones, cesiones, cambios de nombre o domicilio del titular, renunciaciones y licencias de lo arriba mencionado, propósitos para los cuales se les otorga poder para que lleven a cabo ante dichas autoridades todas las acciones necesarias para los propósitos indicados, como radicar solicitudes, hacer declaraciones, reclamaciones, formular descripciones, realizar enmiendas o modificaciones, interponer recursos de

MARTHA SOFÍA SARMIENTO SOLANO - TRADUCTORA OFICIAL
Carrera 11D # 124 - 51 Apto. 809 Int. 2 - (571) 2139034 Bogotá - Colombia
E-mail: mssarmiento2@yahoo.com

Martha S. Sarmiento Solano
Martha S. Sarmiento S.

Traductora Oficial Juramentada
Resolución No. 835 Minjusticia

oposición y apelaciones; pagar todos los impuestos y cuotas y hacer cualquier otro pago establecido por ley; recibir todos los documentos y dineros y emitir el descargo correspondiente; cumplir con cualquier otro requerimiento y tomar, en general, todas las medidas que consideren apropiadas y oportunas para defender y proteger la Propiedad Industrial de la Compañía en el evento de infracciones, oposiciones, procesos para cancelación o anulación, imposición de sanciones, presentar antecedentes ante las Cortes y Tribunales. Además, quedan facultados para comparecer como demandantes o demandados ante Jueces competentes, también se les da poder para negociar, solicitar arbitraje, ceder, recibir, dimitir, rescindir o desistir, apelar, ratificar y todos los poderes legales adicionales que sean necesarios. También se declara que a partir de ahora todas las acciones que realicen dichos abogados respaldando este Poder de Representación y para beneficio de la Compañía son buenas y válidas. Adicionalmente se les otorga facultades para sustituir este Poder y si es necesario revocar dichas sustituciones.

TERCERO: Con el propósito de cumplir con los artículos 597 y 543 del Código Colombiano de Comercio, dichos abogados quedan facultados para recibir notificaciones judiciales y designar abogados judicial y extrajudicialmente.

FIRMADO EN: Houston, Texas **El** 31 de mayo de 2011

POR: (Firma Autógrafa)
James W. Ferguson

(Firma Autógrafa)
Notario Público (Firma)

(Requiere de Apostilla)



NOTARIO PÚBLICO ESTADO DE TEXAS	VALORIE CASEY NOTARIO PÚBLICO ESTADO DE TEXAS MI COMISIÓN FINALIZA EL 10-16-2014
------------------------------------	--

MARTHA SOFÍA SARMIENTO SOLANO - TRADUCTORA OFICIAL
Carrera 11D # 124 - 51 Apto. 609 Int. 2 - (571) 2139034 Bogotá - Colombia
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El suscrito Notario Público, certifica que el Señor James W. Ferguson, compareció ante mí y firmó el documento anterior; que lo conozco personalmente y estoy seguro que él tiene la facultad legal para otorgarlo; que él es el Vicepresidente Principal y Asesor Legal General Adjunto de **HALLIBURTON ENERGY SERVICES, INC.**, y por consiguiente está autorizado para expedir y otorgar dicho documento. Que la Compañía está organizada bajo las leyes de Delaware y su domicilio es el 2601 Beltline Road, Carrollton, Texas 75006, Estados Unidos de América. Además certifico que el acto para el cual se expide y otorga este documento está incluido entre los que constituyen el objeto corporativo de la mencionada Compañía.

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Bogotá, 14 de Julio de 2011

Martha S. Sarmiento Solano
Martha S. Sarmiento S.

Traductora Oficial Juramentada
Resolución No. 835 Minjusticia

SISTEMA Y MÉTODO PARA AJUSTAR DINÁMICAMENTE EL CENTRO DE GRAVEDAD DE UN APARATO DE PERFORACIÓN

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CAMPO TÉCNICO DE LA INVENCION

Esta invención se relaciona, en general, con la perforación de un hoyo que atraviesa una formación subterránea que contiene un fluido usando cargas huecas y, en particular, con un aparato y un método para ajustar dinámicamente el centro de gravedad de un aparato de perforación.

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ANTECEDENTES DE LA INVENCION

Sin limitar el alcance de la presente invención, sus antecedentes se describirán con referencia a la perforación de una formación subterránea con un aparato de perforación con carga hueca, como un ejemplo.

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Después de perforar varias secciones de un hoyo subterráneo que atraviesa una formación, los tramos individuales de conductos tubulares de metal de diámetros relativamente grandes típicamente se aseguran de forma conjunta para formar una sarta de revestimiento que se posiciona dentro del hoyo. Esta sarta de revestimiento aumenta la integridad del hoyo y proporciona una trayectoria para producir fluidos desde los intervalos de producción hacia la superficie. Convencionalmente, la sarta de revestimiento se cementa dentro del hoyo. Para producir fluidos hacia dentro de la sarta de revestimiento, se debe hacer una abertura hidráulica o perforación a través de la sarta de revestimiento, el cemento y una corta distancia dentro de la formación.

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Típicamente, estas perforaciones se crean mediante la detonación de unas series de cargas huecas localizadas dentro de la sarta de revestimiento que se posicionan de forma adyacente a la formación deseada. Específicamente, uno o más portadores de carga se cargan con cargas huecas que se conectan con un dispositivo de detonación, tal como un cordón de detonación. Los portadores de carga se conectan entonces dentro de una sarta de herramientas que se baja hacia dentro del hoyo revestido en el extremo de la sarta de producción, cable de alambre, cable sólido de alambre, tubería de producción en espiral o similar. Una vez que los portadores de carga se posicionan correctamente en el hoyo de manera que las cargas huecas están adyacentes a la formación a ser perforada, las cargas huecas se detonan. Durante la detonación, las cargas huecas crean chorros que explotan a través de escalopes o huecos en el

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portador. Cada chorro crea una abertura hidráulica a través de la tubería de revestimiento y el cemento y entra en la formación formando una perforación.

Se ha encontrado, sin embargo, que en ocasiones es deseable perforar un hoyo en una dirección particular o rango de direcciones en relación con el hoyo. Por ejemplo, en un pozo desviado, inclinado u horizontal, es frecuentemente beneficioso formar perforaciones en la
5 dirección ascendente, dirección descendente o ambas. Se han hecho intentos para alcanzar este objetivo de perforar pozos en direcciones particulares. Un método para orientar las cargas de perforación en el fondo del pozo requiere que las cargas se monten rígidamente en un portador de pistola de manera que las mismas apunten hacia las direcciones deseadas en
10 relación con el portador. El portador de pistola entonces se transporta hacia dentro de un hoyo y lo mismo se presiona de manera lateral físicamente hacia un lado del hoyo de forma que el portador de pistola busque la parte baja del hoyo debido a la gravedad, o el portador de pistola se soporta de manera rotable con su centro de gravedad lateralmente desplazado en relación con el hoyo. Este método se basa en la rotación del portador de pistola en el hoyo, de
15 manera que el portador de pistola puede orientarse en relación con la fuerza de gravedad. Frecuentemente, tal rotación de orientación es poco fiable debido a la fricción entre el portador de pistola y el hoyo, fragmentos en el hoyo o similares.

Más recientemente, el cesionario de la presente invención ha desarrollado una pistola de perforación que incluye un portador de pistola tubular, cargas de perforación múltiples,
20 estructuras de montaje de cargas múltiples y soportes de rotación múltiple. El aparato de perforación internamente orientado ha proporcionado satisfactoriamente un incremento de la fiabilidad en la orientación de cargas de perforación para disparar en las direcciones deseadas en un pozo. En este diseño, la dirección o direcciones de las perforaciones se establecen cuando la pistola se ensambla en su fábrica.

Se ha encontrado, sin embargo, que en ciertas instalaciones, es necesario evitar
25 disparos en una dirección o direcciones particulares. Por ejemplo, uno o más conductos de comunicación o líneas de control pueden extenderse a lo largo del exterior de la sarta de revestimiento. Durante la instalación, estos conductos comúnmente causan daño alrededor de la sarta de revestimiento de manera tal que la localización exacta de estas líneas sólo se puede
30 determinar después de la instalación mediante, por ejemplo, un registro del pozo.

Por consiguiente ha surgido una necesidad de un aparato y método operable para lograr una confiable orientación en el fondo del pozo de las cargas huecas en un aparato de perforación de manera tal que las cargas huecas disparen en las direcciones deseadas. Además, ha surgido una necesidad de un aparato y método operable para lograr una confiable

orientación en el fondo del pozo de las cargas huecas en un aparato de perforación de manera tal que las cargas huecas no disparen en direcciones indeseadas.

SUMARIO DE LA INVENCION

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La presente invención descrita en la presente comprende un aparato y método para ajustar dinámicamente el centro de gravedad de un aparato de perforación. El aparato y método de la presente invención son operables para lograr una confiable orientación de las cargas huecas en el fondo del pozo en un aparato de perforación de manera tal que las cargas
10 huecas disparen en las direcciones deseadas. Además, el aparato y método de la presente invención son operables para lograr una confiable orientación de las cargas huecas en el fondo del pozo en un aparato de perforación de manera tal que las cargas huecas no disparen en direcciones indeseadas.

En un aspecto, la presente invención se dirige hacia un aparato de perforación usado
15 para perforar un pozo subterráneo. El aparato de perforación incluye un portador de pistola generalmente tubular que tiene un sostenedor de carga montado de manera rotatable en el mismo. Al menos una carga hueca se monta en el sostenedor de carga y es operable para perforar el pozo durante la detonación. Un sistema de peso dinámicamente ajustable se asocia de manera operable al sostenedor de carga. El sistema de peso dinámicamente ajustable es
20 operable para ajustar el centro de gravedad del sostenedor de carga de manera que la gravedad provocará que el sostenedor de carga rote dentro del portador de pistola para posicionar al menos una carga hueca en una dirección circunferencial deseada en relación con el pozo previo a la perforación.

En una modalidad, el sistema de peso dinámicamente ajustable incluye una pluralidad
25 de pesos discretos que se acoplan individualmente al sostenedor de carga en una pluralidad de localizaciones longitudinales. En esta modalidad, para cada una de las localizaciones longitudinales, el sostenedor de carga puede incluir una pluralidad de aberturas distribuidas circunferencialmente de manera que las aberturas se distribuyan uniformemente en incrementos de aproximadamente 15 y 60 grados. Alternativamente, para cada una de las
30 localizaciones longitudinales, el sostenedor de carga puede incluir una ranura que se extiende circunferencialmente que se puede extender circunferencialmente entre aproximadamente 90 y 180 grados.

En otra modalidad, el sistema de peso dinámicamente ajustable incluye una pluralidad de tubos que se extienden longitudinalmente operables para contener un material pesado

dentro de los mismos. En una modalidad adicional, el sistema de peso dinámicamente ajustable incluye pesos formados a partir de un material maleable. En aún otra modalidad, el sistema de peso dinámicamente ajustable incluye un tubo de peso que es rotatable en relación con el sostenedor de carga. En cualquiera de estas modalidades, al menos una carga hueca
5 puede incluir una pluralidad de cargas huecas que se pueden posicionar en el sostenedor de carga para disparar sustancialmente en la misma dirección circunferencial o las cargas huecas se pueden posicionar en el sostenedor de carga para disparar en múltiples direcciones circunferenciales.

En otro aspecto, la presente invención se dirige a un aparato de perforación utilizado
10 para perforar un pozo subterráneo. El aparato de perforación incluye un portador de pistola generalmente tubular que tiene un tubo de carga montado de manera rotatable en el mismo. El tubo de carga incluye una pluralidad de ranuras que se extienden circunferencialmente. Al menos una carga hueca se monta en el tubo de carga y es operable para perforar el pozo durante la detonación. Un sistema de peso dinámicamente ajustable se acopla al tubo de
15 carga. El sistema de peso dinámicamente ajustable incluye una pluralidad de pesos discretos que se acoplan al tubo de carga en las ranuras de manera que la localización circunferencial de los pesos es ajustable a lo largo de las ranuras para ajustar el centro de gravedad del tubo de carga de manera que la gravedad provocará que el tubo de carga rote dentro del portador de pistola para posicionar al menos una carga hueca en una dirección circunferencial en
20 relación con el pozo previo a la perforación.

En una modalidad, las ranuras adyacentes en el tubo de carga se extienden en direcciones circunferencialmente opuestas. En otra modalidad, los pesos se unen al tubo de carga usando pernos que son selectivamente desplazables dentro de las ranuras.

En otro aspecto, la presente invención se dirige a un método para perforar un pozo
25 subterráneo. El método incluye identificar al menos una dirección circunferencial indeseada asociada con un intervalo de perforación en el pozo; ajustar los componentes de un sistema de peso dinámicamente ajustable para cambiar el centro de gravedad de un sostenedor de carga montado de manera rotatable dentro de un portador de pistola; posicionar el portador de pistola dentro del intervalo de perforación en el pozo; alinear gravitacionalmente al menos
30 una carga hueca montada en el sostenedor de carga en al menos una dirección circunferencial deseada en relación con el pozo que no se corresponda con al menos una dirección circunferencialmente indeseada; y disparar al menos una carga hueca para perforar el pozo en al menos una dirección circunferencialmente deseada.

El método puede incluir además relocalizar los pesos discretos circunferencialmente alrededor del sostenedor de carga. Esto se puede lograr relocalizando los pesos discretos en relación con las aberturas distribuidas circunferencialmente en el sostenedor de carga o relocalizando los pesos discretos en relación con las ranuras extendidas circunferencialmente en el sostenedor de carga. Alternativamente, el método puede incluir cambiar la cantidad del material pesado en al menos un tubo que se extiende longitudinalmente, remodelar el material maleable dispuesto dentro del sostenedor de carga o rotar un tubo de peso en relación con el sostenedor de carga.

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BREVE DESCRIPCIÓN DE LAS FIGURAS

Para un entendimiento más completo de las características y ventajas de la presente invención, ahora se hace referencia a la descripción detallada de la invención junto con las figuras acompañantes en las cuales los números de referencia correspondientes en las diferentes figuras se refieren a las partes correspondientes y en las cuales:

La Figura 1 es una ilustración esquemática de una plataforma mar adentro de petróleo y gas que opera una pluralidad de aparatos para dinámicamente ajustar el centro de gravedad de aparatos de perforación de la presente invención;

La Figura 2 es una vista en sección transversal de una modalidad de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención;

Las Figuras 3A-3B son vistas laterales y en sección transversal de una modalidad de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención;

Las Figuras 4A-4B son vistas laterales y en sección transversal de una modalidad de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención;

La Figura 5 es una vista en sección transversal de una modalidad de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención;

La Figura 6 es una vista en sección transversal de una modalidad de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención;

Las Figuras 7A-7B son vistas en sección transversal de una modalidad de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención;

Las Figuras 8A-8G son varias vistas de una modalidad de un aparato para ajustar
5 dinámicamente el centro de gravedad de un aparato de perforación de la presente invención;

Las Figuras 9A-9B son vistas laterales y superiores de una modalidad de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención; y

Las Figuras 10A-10C son varias vistas de una modalidad de un aparato para ajustar
10 dinámicamente el centro de gravedad de un aparato de perforación de la presente invención.

DESCRIPCIÓN DETALLADA DE LA INVENCION

Aunque la fabricación y el uso de las diferentes modalidades de la presente invención
15 se tratan en detalle más adelante, se debería apreciar que la presente invención proporciona muchos conceptos inventivos aplicables que se pueden poner en práctica en una gran variedad de contextos específicos. Las modalidades específicas debatidas en la presente son meramente ilustrativas de las formas específicas de hacer y usar la invención, y no delimitan el alcance de la presente invención.

20 Con referencia inicialmente a la Figura 1, se ilustra esquemáticamente y generalmente se designa como 10 una pluralidad de aparatos para ajustar dinámicamente el centro de gravedad de aparatos de perforación que operan en una plataforma mar adentro de petróleo y gas. Una plataforma semi-sumergible 12 se centra sobre una formación de petróleo y gas sumergida 14 localizada debajo del lecho marino 16. Un conducto submarino 18 se extiende
25 desde la cubierta 20 de la plataforma 12 hasta la instalación del cabezal de pozo 22 incluyendo dispositivos que evitan los reventones submarinos 24. La plataforma 12 tiene un aparato de levantamiento 26 y una torre de perforación 28 para elevar y bajar las sarts de tubería, tales como una sarta de trabajo 30.

Un hoyo 32 se extiende a través de diferentes estratos de tierra incluyendo la
30 formación 14. Una tubería de revestimiento 34 se cementa dentro del hoyo 32 con el cemento 36. La sarta de trabajo 30 incluye varias herramientas tales como una pluralidad de aparatos de perforación o pistolas 38. Cuando se desea perforar la tubería de revestimiento 34, la sarta de trabajo 30 se baja a través de la tubería de revestimiento 34 hasta que las pistolas de

perforación 38 se posicionan apropiadamente en relación con la formación 14. Después de eso, las cargas huecas dentro de la sarta de pistolas de perforación 38 se disparan secuencialmente, lo mismo en una dirección pozo arriba hacia pozo abajo que pozo abajo hacia pozo arriba. Durante la detonación, las camisas de las cargas huecas forman chorros
5 que crean unas series espaciadas de perforaciones que se extienden por fuera a través de la tubería de revestimiento 34, el cemento 36 y hacia dentro de la formación 14, permitiendo de esta forma la comunicación de fluidos entre la formación 14 y el hoyo 32.

En la modalidad ilustrada, el hoyo 32 tiene una parte inicial, generalmente vertical 40 y una parte inferior, generalmente desviada 42 que se ilustra estando horizontal. Se debe
10 observar, sin embargo, por aquellos expertos en el arte que los aparatos para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención es igualmente bien adecuado para su uso en otras configuraciones de pozo que incluye, pero no se limitan a, pozos inclinados, pozos sin restricciones, pozos no desviados, pozos multilaterales y similares. Además, aunque se ha representado en la Figura 1 una operación
15 mar adentro, el aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención es igualmente bien adecuado para su uso en operaciones en tierra.

La sarta de trabajo 30 incluye un empacador 44 que se puede acoplar de manera sellada con la tubería de revestimiento 34 y se ilustra en la parte vertical 40 del hoyo 32. En
20 el extremo inferior de la sarta de trabajo 30 está la sarta de pistola que incluye la pluralidad de pistolas de perforación 38, un niple con puertos 46 y un cabezal de disparo 48. En la modalidad ilustrada, las pistolas de perforación 38 incluyen características de orientación interna que permiten una orientación confiable del tubo de carga dentro del portador de pistola como se describe en la patente de los Estados Unidos No. 6,595,290 concedida a
25 Halliburton Energy Services, Inc. el 22 de julio de 2003, la cual se incorpora en la presente como referencia para todos los propósitos.

Con referencia ahora a la Figura 2, en la misma se representa un aparato de perforación que incluye un aparato para ajustar dinámicamente el centro de gravedad del
aparato de perforación de la presente invención que generalmente se designa como 100. En la
30 siguiente descripción del aparato 100 así como de otros aparatos y métodos descritos en la presente, los términos direccionales tales como “encima”, “debajo”, “superior”, “inferior” y similares se usan por conveniencia en referencia a las ilustraciones y se debe entender que las diferentes modalidades de la invención se pueden usar en diferentes orientaciones tales como

inclinada, invertida, horizontal, vertical y similares y en varias configuraciones, sin separarse de los principios de la invención.

La pistola 100 incluye una pluralidad de cargas huecas 102 que se montan de forma segura en un sostenedor de carga que se representa como el tubo de carga 104. El tubo de carga 104 se monta de manera rotable dentro de un portador de pistola 106. Preferiblemente, el tubo de carga 104 se hace de una tubería cilíndrica, pero se debe entender que no es necesario que el tubo de carga 104 sea tubular o tenga una forma cilíndrica de acuerdo con los principios de la invención. El tubo de carga 104 incluye múltiples soportes 108 que permiten que el tubo de carga 104 rote dentro del portador de pistola 106. Esta forma de soportar de manera rotable el tubo de carga 104 evita que las cargas 102 o cualquier otra parte del tubo de carga 104 hagan contacto con el interior del portador de pistola 106.

Cada uno de los soportes 108 incluye elementos de rodamiento o cojinetes 110 que contactan el interior del portador de pistola 106. Por ejemplo, los cojinetes 110 pueden ser cojinetes de bola, cojinetes de rodillos, cojinetes planos o similares. Los cojinetes 110 posibilitan que los soportes 108 suspendan el tubo de carga 104 en el portador de pistola 106 y permitan la rotación del mismo. Además, se pueden posicionar cojinetes de empuje opcionales 112 entre cada extremo del tubo de carga 104 y el portador de pistola 106 de manera que los cojinetes de empuje 112 hagan contacto con los dispositivos 114 unidos a cada extremo del portador de pistola 106. Cada dispositivo 114 puede ser unos tandems que se usan para acoplar dos pistolas entre sí, un tapón macho usado para terminar una sarta de pistola, un cabezal de disparo, o cualquier otro tipo de dispositivo que se pueda unir al portador de pistola 106. Al igual que los cojinetes 110 descritos anteriormente, los cojinetes de empuje 112 pueden ser cualquier tipo de cojinetes. Los cojinetes de empuje 112 soportan el tubo de carga 104 contra la carga axial dentro del portador de pistola 106, al mismo tiempo que permiten que el tubo de carga 104 rote dentro del portador de pistola 106.

El tubo de carga 104, las cargas 102 y otras partes de la pistola 100 soportadas en el portador de pistola 106 mediante los soportes 108 incluyen, por ejemplo, un cordón de detonación 166 que se extiende a cada una de las cargas y partes de los soportes, son partes de un conjunto de ensamble de rotación 118. Mediante el desplazamiento de un centro de gravedad 120 del ensamble 118 en relación con un eje rotacional longitudinal 122 de los cojinetes 110, el ensamble 118 se presiona por gravedad para que rote hacia una posición específica en la cual el centro de gravedad 120 se localiza directamente debajo del eje rotacional 122.

Un ensamble 118 puede, debido a la construcción de varios elementos del mismo, tener inicialmente el centro de gravedad 120 en una posición deseada en relación con las cargas 102. Sin embargo, para asegurar que las cargas 102 estén dirigidas a disparar en las direcciones respectivas predeterminadas, el centro de gravedad 120 puede reposicionarse usando un sistema de peso dinámicamente ajustable que se representa como los pesos 124. En la modalidad ilustrada, en el lado izquierdo de la Figura 2, los pesos 124 se adicionan al ensamble 118 para dirigir las cargas 102 a disparar hacia arriba, mientras en el lado derecho de la Figura 2, los pesos 124 se adicionan al ensamble 118 para dirigir las cargas 102 a disparar hacia abajo. Como se debate en mayor detalle a continuación, los pesos 124 se pueden posicionar de otra manera para dirigir las cargas 102 a disparar en cualquier dirección deseada, o combinación de direcciones y para evitar disparos en direcciones indeseadas.

El portador de pistola 106 se proporciona con partes de espesor de pared reducido 126, que se extienden circunferencialmente sobre el portador 106 por fuera sobre cada una de las cargas 102. Por consiguiente, cuando las cargas 102 rotan dentro del portador 106, las mismas se mantienen dirigidas a disparar a través de las partes 126. Las partes de espesor de pared reducido 126 se pueden formar en el portador 106 mediante laminado, forjado, maquinado en torno o cualquier otra técnica adecuada.

Con referencia a continuación a las Figuras 3A y 3B, en las mismas se representan vistas laterales y en sección transversal de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención que generalmente se designa como 130. El aparato 130 incluye un sostenedor de carga representado como un tubo de carga 132 que aloja una pluralidad de cargas huecas 134. En la modalidad ilustrada, las cargas huecas 134 se configuran en un patrón de fases de 180 grados, sin embargo, aquellos expertos en el arte apreciarán que cualquier número de patrones de fases alternativos de las cargas huecas es posible y se considera dentro del alcance de la presente invención.

El aparato 130 incluye además un sistema de peso dinámicamente ajustable representado como los pesos 136. En la modalidad ilustrada, cada uno de los pesos 136 incluye una parte roscada que es operable para recibir en la misma un perno roscado complementario 138. Los pesos 136 se unen consecuentemente al tubo de carga 132 pasando la parte del eje de un perno 138 a través de una de la pluralidad de aberturas 140 en el tubo de carga 132 y luego se acopla ese perno 138 de manera rotable a uno de los pesos 136. Como se ilustra, cada localización longitudinal del tubo de carga 132 que se diseña para recibir un peso 136 tiene ocho aberturas 140 que están espaciadas circunferencialmente en incrementos de 45 grados. Se debe entender por aquellos expertos en el arte, sin embargo, que cualquier número

de aberturas que tengan cualquier espaciado circunferencialmente uniforme o no uniforme deseado es posible y se considera dentro del alcance de la presente invención, siempre que la integridad estructural del tubo de carga 132 se mantenga. Por ejemplo, se puede desear tener aberturas que estén espaciadas circunferencialmente de manera uniforme
5 alrededor de un tubo de carga en incrementos de aproximadamente entre 15 y 60 grados.

Como se usa en la presente, el término dinámicamente ajustable se refiere a la capacidad de cambiar el centro de gravedad de un aparato de perforación en el campo por el contrario de sólo cuando se fabrica el aparato de perforación. Esta capacidad proporciona la versatilidad para hacer ajustes al aparato 130 que no sólo permitirán que el personal del
10 campo dispare en una dirección deseada sino que además evitarán disparos en una dirección indeseada, tal como en la dirección de una línea de control dispuesta en el exterior de la sarta de revestimiento. Continuando con este ejemplo, si una o más líneas de control se posicionan en el exterior de la sarta de revestimiento, es imperativo evitar provocar daño a las líneas de control durante el proceso de perforación. Como estas líneas de control comúnmente se
15 encuentran en una configuración en espiral alrededor de la sarta de revestimiento durante la instalación, la localización actual de las líneas de control se debe determinar antes de perforar el pozo mediante, por ejemplo, el registro del pozo. Una vez que se conoce la localización circunferencial de las líneas de control para cada profundidad del pozo, la presente invención permite que el personal de campo ajuste a la medida la sarta de pistola de perforación de
20 manera que las líneas de control se puedan evitar y el pozo se pueda perforar en las orientaciones direccionales deseadas.

En la modalidad ilustrada, esto se logra reposicionando los pesos 136 en relación con cualquiera de las aberturas respectivas 140 espaciadas circunferencialmente alrededor del tubo de carga 132. Por ejemplo, si el tubo de carga 132 estuviera instalado dentro de un
25 portador de pistola como se configura en la Figura 3B y se utilizara en un pozo horizontal, los pesos 136 podrían provocar que el tubo de carga 132 rote hacia la posición representada en la Figura 3B en donde las cargas huecas 134 podrían disparar a 0 y 180 grados en el pozo. Si los pesos 136 se movieran cada uno hacia la siguiente posición adyacente, las cargas huecas 134 podrían disparar a 45 y 255 grados en el pozo. Igualmente, si los pesos 136 se movieran cada
30 uno nuevamente hacia la siguiente posición adyacente, las cargas huecas 134 podrían disparar a 90 y 270 grados en el pozo. Consecuentemente, las direcciones en que las cargas huecas perforarán el pozo se pueden ajustar dinámicamente por el personal de campo luego de que se haya determinado la localización de cualquier riesgo del hoyo.

Aunque las Figuras 3A-3B han representado a los aparatos 130 teniendo un peso posicionado entre la carga hueca adyacente, se debe entender por aquellos expertos en el arte que no se requiere ninguna relación particular entre el número de pesos y el número de cargas huecas en un aparato de perforación dado. El número y configuración de los pesos y las
5 cargas huecas variará basado en factores tales como los disparos por pie deseados, el diámetro del tubo de carga, la masa explosiva de las cargas, el tamaño de los pesos, el espaciamiento entre las cargas y similares. El factor importante es que el centro de gravedad sea dinámicamente ajustable para provocar que el tubo de carga rote dentro del portador de pistola hacia la posición deseada.

10 Con referencia a continuación a las Figuras 4A y 4B, en las mismas se representan vistas laterales y en sección transversal de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención que generalmente se designa como 150. El aparato 150 incluye un sostenedor de carga representado como un tubo de carga 152 que aloja una pluralidad de cargas huecas 154. En la modalidad ilustrada, las cargas
15 huecas 154 se configuran en un patrón de fases de 180 grados, sin embargo, aquellos expertos en el arte apreciarán que cualquier número de patrones de fases alternativos de las cargas huecas es posible y se considera dentro del alcance de la presente invención.

El aparato 150 incluye además un sistema de peso dinámicamente ajustable representado como los pesos 156. En la modalidad ilustrada, cada uno de los pesos 156
20 incluye una parte roscada que es operable para recibir en la misma un perno roscado complementario 158. Los pesos 156 se unen consecuentemente al tubo de carga 152 pasando la parte del eje de un perno 158 a través de una ranura 160 en el tubo de carga 152 y luego se acopla de manera rotatable ese perno 158 a uno de los pesos 156. Como se ilustra, cada localización longitudinal del tubo de carga 152 que se diseña para recibir un peso 156 tiene
25 una ranura 160 que atraviesa circunferencialmente 180 grados del tubo de carga 152. Las ranuras adyacentes 160 del aparato 150 se configuran de manera que se extienden sobre los lados opuestos del tubo de carga 152. Este diseño mejora la integridad estructural del tubo de carga 152 y permite una variabilidad infinita en el centro de gravedad del aparato 150. En ciertas implementaciones, los pesos 156 se pueden colocar en cada uno de las ranuras 160. En
30 otras implementaciones, puede ser deseable tener los pesos 156 en cada ranura 160 de manera que cada uno de los pesos 156 se pueda posicionar en la misma posición circunferencial. Se debe entender por aquellos expertos en el arte que las ranuras 160 pueden tener otras orientaciones circunferenciales y pueden tener otros arreglos de espaciamientos relativos,

uniformes y no uniformes, sin separarse de los principios de la presente invención, siempre que se mantenga la integridad estructural del tubo de carga 152.

Como se debatió anteriormente, la combinación de las ranuras 160 y los pesos 156 permite los ajustes dinámicos en el centro de gravedad de un aparato de perforación en el campo. Esta capacidad proporciona la versatilidad para hacer ajustes al aparato 150 que no sólo permitirán que el personal del campo dispare en una dirección deseada sino que además evitarán disparos en una dirección indeseada, tal como en la dirección de una línea de control u otros elementos de riesgo dispuestos en el exterior de la sarta de revestimiento o dentro de la sarta de revestimiento. Específicamente, en la modalidad ilustrada, esto se logra reposicionando circunferencialmente los pesos 156 junto con las ranuras 160, aflojando los pernos 158, deslizando los pesos 156 hacia las posiciones circunferenciales deseadas y reasegurando los pesos 156 al tubo de carga 152 con los pernos 158. Si el tubo de carga 152 se instalara dentro de un portador de pistola como se carga en la Figura 4B y se utilizara en un pozo horizontal, los pesos 156 podrían provocar que el tubo de carga 152 rote hacia la posición representada en la Figura 4B en donde las cargas huecas 154 podrían disparar a 0 y 180 grados en el pozo. Reposicionar los pesos 156 junto con las ranuras 160, como se describió anteriormente, permitiría disparar en cualquier dirección circunferencial deseada. Consecuentemente, las direcciones en que las cargas huecas perforarán el pozo se pueden ajustar dinámicamente por el personal de campo luego de que se haya determinado la localización de cualquier elemento de riesgo en el hoyo.

Con referencia a continuación a la Figura 5, en la misma se representa una vista en sección transversal de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención que generalmente se designa como 170. El aparato 170 incluye un sostenedor de carga representado como un tubo de carga 172 que aloja una pluralidad de cargas huecas (no representado). El aparato 170 incluye además un sistema de peso dinámicamente ajustable 174 que se representa por una pluralidad de tubos 176. Los tubos 176 se extienden al menos parcialmente de manera longitudinal dentro del tubo de carga 172 y son operables para contener un material pesado tal como un fluido o un sólido. Como se ilustra, el aparato 170 incluye siete tubos tubulares 176 que se distribuyen circunferencialmente dentro del tubo de carga 172 en incrementos de 30 grados. Se debe entender por aquellos expertos en el arte que los tubos 176 pueden tener otras orientaciones circunferenciales, uniformes y no uniformes, dentro del tubo de carga 172 sin separarse de los principios de la presente invención. Igualmente, aunque los tubos 176 se representan teniendo una sección transversal tubular, los tubos 176 podrían alternativamente tener otras secciones

transversales incluyendo, pero no limitándose a, secciones transversales ovaladas, secciones transversales rectangulares, secciones transversales en forma de arco y similares. Además, aquellos expertos en el arte reconocerán que no todos los tubos 176 necesitan tener la misma sección transversal o ser del mismo tamaño.

5 En funcionamiento, el sistema de peso dinámicamente ajustable 174 del aparato 170 permite que el personal de campo haga ajustes dinámicos en el centro de gravedad de un aparato de perforación en el campo. Esta capacidad proporciona la versatilidad para hacer ajustes al aparato 170 que no sólo permitirá que el personal del campo dispare en una dirección deseada sino que además evitará disparos en una dirección indeseada, tal como en
10 la dirección de una línea de control u otro elemento de riesgo dispuesto en el exterior de la sarta de revestimiento o dentro de la sarta de revestimiento. Específicamente, en la modalidad ilustrada, esto se logra adicionando o reduciendo el peso dentro de los tubos 176 mediante, por ejemplo, la adición o eliminación de un fluido tal como agua de los tubos 176. Cuando se ajusta el peso en los diferentes tubos 176 se puede lograr la rotación pozo abajo deseada del
15 tubo de carga 172. Consecuentemente, las direcciones en que las cargas huecas perforarán el pozo se pueden ajustar dinámicamente por el personal de campo luego de que se haya determinado la localización de cualquier elemento de riesgo en el hoyo.

Con referencia a continuación a la Figura 6, en la misma se representa una vista en sección transversal de un aparato para ajustar dinámicamente el centro de gravedad de un
20 aparato de perforación de la presente invención que generalmente se designa como 180. El aparato 180 incluye un sostenedor de carga representado como un tubo de carga 182 que aloja una pluralidad de cargas huecas (no representado). El aparato 180 incluye además un sistema de peso dinámicamente ajustable 184 que se representa por una pluralidad de tubos 186. Los tubos 186 se extienden al menos parcialmente de manera longitudinal a lo largo del
25 exterior del tubo de carga 182 y son operables para contener un material pesado tal como un fluido o un sólido. Como se ilustra, el aparato 180 incluye siete tubos tubulares 186 que se distribuyen circunferencialmente dentro del tubo de carga 182 en incrementos de 30 grados. Se debe entender por aquellos expertos en el arte que los tubos 186 pueden tener otras orientaciones circunferenciales, uniformes y no uniformes, dentro del tubo de carga 182 sin
30 separarse de los principios de la presente invención. Igualmente, aunque los tubos 186 se representan teniendo una sección transversal tubular, los tubos 186 podrían alternativamente tener otras secciones transversales incluyendo, pero no limitándose a, secciones transversales ovaladas, secciones transversales rectangulares, secciones transversales en forma de arco y

similares. Además, aquellos expertos en el arte reconocerán que no todos los tubos 186 necesitan tener la misma sección transversal o ser del mismo tamaño.

En funcionamiento, el sistema de peso dinámicamente ajustable 184 del aparato 180 permite que el personal de campo haga ajustes dinámicos en el centro de gravedad de un aparato de perforación en el campo. Esta capacidad proporciona la versatilidad para hacer
5 ajustes al aparato 180 que no sólo permitirá que el personal del campo dispare en una dirección deseada sino que además evitará disparos en una dirección indeseada, tal como en la dirección de una línea de control u otro elemento de riesgo dispuesto en el exterior de la sarta de revestimiento o dentro de la sarta de revestimiento. Específicamente, en la modalidad
10 ilustrada, esto se logra adicionando o reduciendo el peso dentro de los tubos 186 mediante, por ejemplo, la adición o eliminación de un fluido tal como agua de los tubos 186. Cuando se ajusta el peso en los diferentes tubos 186, se puede lograr la rotación pozo abajo deseada del tubo de carga 182. Consecuentemente, las direcciones en que las cargas huecas perforarán el pozo se pueden ajustar dinámicamente por el personal de campo luego de que se haya
15 determinado la localización de cualquier elemento de riesgo en el hoyo.

Aunque las Figuras 5 y 6 han representado tubos localizados respectivamente dentro y fuera del tubo de carga que son operables para recibir un material pesado dentro del mismo, aquellos expertos en el arte podrían reconocer que configuraciones alternas también podrían usarse y se considerarían dentro del alcance de la presente invención incluyendo, pero no
20 limitándose a, formar uno o más pasillos en la pared del tubo de carga o conductos tubulares similares operables para recibir un material pesado dentro del mismo.

Con referencia a continuación a las Figuras 7A y 7B, en las mismas se representan unas vistas en sección transversal de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención que generalmente se designa
25 como 190. El aparato 190 incluye un sostenedor de carga representado como un tubo de carga 192 que aloja una pluralidad de cargas huecas (no representado). El aparato 190 incluye además un sistema de peso dinámicamente ajustable 194 que se representa por unos miembros de peso maleables 196 que se pueden formar a partir de un metal tal como plomo o un polímero. Los miembros de peso maleables 196 se pueden extender al menos parcialmente
30 de manera longitudinal a lo largo del interior del tubo de carga 192 o pueden ser elementos de peso discretos similares a los pesos 136 y 156 descritos anteriormente. Como se ilustra, cada miembro de peso maleable 196 se acopla al tubo de carga 192 usando uno o más pernos 198. En operación, el sistema de peso dinámicamente ajustable 194 del aparato 190 permite que el personal de campo haga ajustes dinámicos en el centro de gravedad de un aparato de

perforación en el campo. Esta capacidad proporciona la versatilidad para hacer ajustes al aparato 190 que no sólo permitirá que el personal del campo dispare en una dirección deseada sino que además evitará disparos en una dirección indeseada, tal como en la dirección de una línea de control u otro elemento de riesgo dispuesto en el exterior de la sarta de revestimiento o dentro de la sarta de revestimiento. Específicamente, en la modalidad ilustrada, esto se logra aplicando presión o fuerza al material maleable que forma los miembros de peso maleables 196 usando, por ejemplo, una herramienta de ajuste que se dimensiona para extenderse hacia dentro del tubo de carga 192. La localización de al menos una parte de la masa de los miembros de peso maleables 196 entonces se puede ajustar, como se observa en una comparación de las Figuras 7A y 7B, de manera que se puede lograr la rotación pozo abajo deseada del tubo de carga 192. Consecuentemente, las direcciones en que las cargas huecas perforarán el pozo se pueden ajustar dinámicamente por el personal de campo luego de que se haya determinado la localización de cualquier elemento de riesgo en el hoyo.

Con referencia a continuación a las Figuras 8A-8G, en las mismas se representan varias vistas de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención que generalmente se designa como 200. Cuando se ensambla, el aparato 200 forma un ensamble de rotación 202 que se monta de manera rotatable en un portador de pistola en una manera descrita anteriormente. El aparato 200 incluye un sostenedor de carga 204 que soporta una pluralidad de cargas huecas 206. El sostenedor de carga 204 se acopla a las placas de extremo 208. Cada placa de extremo 208 incluye una pluralidad de muescas 210 que se ilustran estando posicionadas circunferencialmente alrededor de las placas de extremo 208 en incrementos de 60 grados, sin embargo, aquellos expertos en el arte reconocerán que esas muescas 210 podrían tener configuraciones alternas incluyendo tener diferentes espaciamiento circunferencial. Además, dependiendo del largo del sostenedor de carga 204, puede ser deseable tener estructuras de adición que son similares a las placas de extremo 208 posicionadas en localizaciones intermedias a lo largo del sostenedor de carga 204 entre ciertas cargas huecas 206. El aparato 200 incluye además un sistema de peso dinámicamente ajustable representado por el tubo de peso 212. El tubo de peso 212 se forma a partir de un miembro sustancialmente tubular que tiene una ventana 214, como se observa mejor en la Figura 8E. En la modalidad ilustrada, la ventana 214 se extiende aproximadamente 120 grados circunferencialmente alrededor del tubo de peso 212, sin embargo, aquellos expertos en el arte reconocerán que la ventana 214 puede tener configuraciones alternas incluyendo tener un ancho circunferencial diferente o múltiples secciones de ventana distribuidas circunferencialmente alrededor del tubo de peso 212. El

tubo de peso 212 incluye secciones de extremo circunferenciales 216 que se dimensionan para recibir justamente las placas de extremo 208. El tubo de peso 212 incluye una pluralidad de raíles 218 que se diseñan para engranarse con las muescas 210 de las placas de extremo 208.

5 En funcionamiento, el sistema de peso dinámicamente ajustable del aparato 200 permite que el personal de campo haga ajustes dinámicos en el centro de gravedad de un aparato de perforación en el campo. Esta capacidad proporciona la versatilidad para hacer ajustes al aparato 200 que no sólo permitirá que el personal del campo dispare en una dirección deseada sino que además evitarán disparos en una dirección indeseada, tal como en
10 la dirección de una línea de control u otro elemento de riesgo dispuesto en el exterior de la sarta de revestimiento o dentro de la sarta de revestimiento. Específicamente, en la modalidad ilustrada, esto se logra insertando el sostenedor de carga 204 dentro del tubo de peso 212 de manera que las cargas huecas 206 se orienten en las direcciones deseadas. Por ejemplo, si el sostenedor de carga 204 se instalara dentro del tubo de peso 212 como se muestra en la
15 Figura 8F y se utilizara en un pozo horizontal, el tubo de peso 212 podría provocar que el ensamble de rotación 202 rote hacia la posición representada en la Figura 8F en donde las cargas huecas 206 podrían disparar a 0 grados en el pozo. Si el sostenedor de carga 204 se rota 60 grados en cualquier dirección para realinear los raíles 218 y las muescas 210, las cargas huecas 206 podrían disparar a 60 grados o 300 grados en el pozo. Consecuentemente,
20 las direcciones en que las cargas huecas perforarán el pozo se pueden ajustar dinámicamente por el personal de campo luego de que se haya determinado la localización de cualquier elemento de riesgo en el hoyo.

Con referencia a continuación a las Figuras 9A-9B, en las mismas se representan vistas laterales y en sección transversal de un aparato para ajustar dinámicamente el centro de
25 gravedad de un aparato de perforación de la presente invención que generalmente se designa como 220. Cuando se ensambla, el aparato 220 forma un ensamble de rotación 222 que se monta de manera rotatable en un portador de pistola en una manera descrita anteriormente mediante los cojinetes 224. El aparato 220 incluye un sostenedor de carga 226 que soporta una pluralidad de cargas huecas 228. El aparato 220 incluye además un sistema de peso
30 dinámicamente ajustable representado por el tubo de peso 230. El tubo de peso 230 se forma a partir de un miembro parcialmente tubular. El sostenedor de carga 226 se monta selectivamente de manera rotatable dentro del tubo de peso 230 de manera que el sostenedor de carga 226 se pueda rotar alrededor de 120 grados circunferencialmente dentro del tubo de peso 230. En funcionamiento, el sistema de peso dinámicamente ajustable del aparato 220

permite que el personal de campo haga ajustes dinámicos en el centro de gravedad de un aparato de perforación en el campo. Esta capacidad proporciona la versatilidad para hacer ajustes al aparato 220 que no sólo permitirá que el personal del campo dispare en una dirección deseada sino que además evitará disparos en una dirección indeseada, tal como en

5 la dirección de una línea de control u otro elemento de riesgo dispuesto en el exterior de la sarta de revestimiento o dentro de la sarta de revestimiento. Específicamente, en la modalidad ilustrada, esto se logra liberando selectivamente una conexión tal como un pasador, un tornillo de ajuste o similares entre el sostenedor de carga 226 y el tubo de peso 230 luego rotando el sostenedor de carga 226 de manera que las cargas huecas 228 se orienten en la

10 dirección deseada. Por ejemplo, si el sostenedor de carga 226 se instala dentro de un tubo de peso 230 como se muestra en la Figura 9A y se utiliza en un pozo horizontal, el tubo de peso 230 podría provocar que el ensamble de rotación 222 rote hacia la posición representada en la Figura 9A en donde las cargas huecas 228 podrían disparar a 0 grados en el pozo. Si se desea otra dirección circunferencial, sin embargo, el sostenedor de carga 226 se puede ajustar

15 incrementalmente en ciertas modalidades, o ajustar infinitamente en otras modalidades, a cualquier posición entre las localizaciones de máximo recorrido que se han descrito anteriormente, como aproximadamente 60 grados desde la vertical, en cualquier dirección en la modalidad ilustrada. Consecuentemente, las direcciones en que las cargas huecas perforarán el pozo se pueden ajustar dinámicamente por el personal de campo luego de que se

20 haya determinado la localización de cualquier elemento de riesgo en el hoyo.

Con referencia a continuación a las Figuras 10A-10C, en las mismas se representan varias vistas de un aparato para ajustar dinámicamente el centro de gravedad de un aparato de perforación de la presente invención que generalmente se designa como 240. El aparato 240 incluye un sostenedor de carga representado por un tubo de carga 242 que se monta de

25 manera rotatable en un portador de pistola de una manera descrita anteriormente mediante los cojinetes 244, como se observa mejor en las Figuras 10A y 10C. El tubo de carga 242 soporta una pluralidad de cargas huecas 246. El aparato 240 incluye además un sistema de peso dinámicamente ajustable representado por el tubo de peso 250, como se observa mejor en las Figuras 10B y 10C. El tubo de peso 250 se forma a partir de un miembro parcialmente

30 tubular. El sostenedor de carga 250 se monta de manera rotatable dentro de un miembro giratorio 252 que se monta dentro del tubo de carga 242 de manera que el tubo de carga 250 se pueda rotar aproximadamente 120 grados circunferencialmente dentro del tubo de carga 242. Uno o más miembros de acople representados por los pasadores 254 se usan para selectivamente evitar la rotación del tubo de peso 250 en relación con el miembro giratorio

252. En funcionamiento, el sistema de peso dinámicamente ajustable del aparato 240 permite que el personal de campo haga ajustes dinámicos en el centro de gravedad de un aparato de perforación en el campo. Esta capacidad proporciona la versatilidad para hacer ajustes al aparato 240 que no sólo permitirá que el personal del campo dispare en una dirección deseada sino que además evitará disparos en una dirección indeseada, tal como en la dirección de una línea de control u otro elemento de riesgo dispuesto en el exterior de la sarta de revestimiento o dentro de la sarta de revestimiento. Específicamente, en la modalidad ilustrada, esto se logra liberando selectivamente la conexión, tal como los pasadores 254, entre el tubo de peso 250 y el miembro giratorio 252, luego rotando el tubo de peso 250 en relación con el miembro giratorio 252 de manera que el tubo de peso 250 se posicione en la orientación deseada en relación con las cargas huecas 246. Por ejemplo, si el tubo de peso 250 se instala en relación con las cargas huecas 246 como se muestra en las Figuras 10B-10C y se utiliza en un pozo horizontal, el tubo de peso 250 podría provocar que el tubo de carga 242 rote hacia la posición representada en las Figuras 10B-10C en donde las cargas huecas 246 podrían disparar a 0 grados en el pozo. Si se desea otra dirección circunferencial, sin embargo, el tubo de peso 250 se puede ajustar incrementalmente en ciertas modalidades o ajustar infinitamente en otras modalidades para cualquier posición entre las localizaciones de máximo recorrido que se han descrito anteriormente, como aproximadamente 60 grados desde la vertical, en cualquier dirección en la modalidad ilustrada. Consecuentemente, las direcciones en que las cargas huecas perforarán el pozo se pueden ajustar dinámicamente por el personal de campo luego de que se haya determinado la localización de cualquier elemento de riesgo en el hoyo.

Mientras esta invención se ha descrito con referencia a modalidades ilustrativas, esta descripción no tiene como objetivo construirse en un sentido limitado. Varias modificaciones y combinaciones de las modalidades ilustrativas así como también otras modalidades de la invención serán evidentes para personas expertas en el arte haciendo referencia a la descripción. Por consiguiente, se pretende que las reivindicaciones anexadas abarquen cualquiera de tales modificaciones o modalidades.

REIVINDICACIONES

1. Un aparato de perforación usado para perforar un pozo subterráneo, el aparato
5 de perforación comprende:

un portador de pistola generalmente tubular;

un sostenedor de carga montado de manera rotatable dentro del portador de pistola;

al menos una carga hueca montada en el sostenedor de carga y operable para perforar
el pozo durante la detonación; y

10 un sistema de peso dinámicamente ajustable asociado de manera operable con el
sostenedor de carga, el sistema de peso dinámicamente ajustable operable para ajustar el
centro de gravedad del sostenedor de carga de manera que la gravedad provocará que el
sostenedor de carga rote dentro del portador de pistola para posicionar al menos una carga
hueca en una dirección circunferencial deseada en relación con el pozo previo a la
15 perforación.

2. El aparato de perforación mencionado en la reivindicación 1 en donde el
sistema de peso dinámicamente ajustable comprende además una pluralidad de pesos
discretos que se acoplan individualmente al sostenedor de carga en una pluralidad de
localizaciones longitudinales.

20 3. El aparato de perforación mencionado en la reivindicación 2 en donde, para
cada una de las localizaciones longitudinales, el sostenedor de carga incluye una pluralidad
de aberturas distribuidas circunferencialmente.

4. El aparato de perforación mencionado en la reivindicación 3 en donde las
aberturas distribuidas circunferencialmente están distribuidas uniformemente en incrementos
25 de entre aproximadamente 15 y aproximadamente 60 grados.

5. El aparato de perforación mencionado en la reivindicación 2 en donde, para
cada una de las localizaciones longitudinales, el sostenedor de carga incluye una ranura que
se extiende circunferencialmente.

6. El aparato de perforación mencionado en la reivindicación 5 en donde las
30 ranuras se extienden circunferencialmente entre aproximadamente 90 y 180 grados.

7. El aparato de perforación mencionado en la reivindicación 1 en donde el
sistema de peso dinámicamente ajustable comprende además una pluralidad de tubos que se
extienden longitudinalmente operables para contener un material pesado dentro de los
mismos.

8. El aparato de perforación mencionado en la reivindicación 1 en donde el sistema de peso dinámicamente ajustable comprende además pesos formados a partir de un material maleable.
9. El aparato de perforación mencionado en la reivindicación 1 en donde el sistema de peso dinámicamente ajustable comprende además un tubo de peso que es rotatable en relación con el sostenedor de carga.
10. El aparato de perforación mencionado en la reivindicación 1 en donde al menos una carga hueca comprende además una pluralidad de cargas huecas y en donde cada una de las cargas huecas se posiciona en el sostenedor de carga para disparar sustancialmente en la misma dirección circunferencial.
11. El aparato de perforación mencionado en la reivindicación 1 en donde al menos una carga hueca comprende además una pluralidad de cargas huecas y en donde las cargas huecas se posiciona en el sostenedor de carga para disparar en múltiples direcciones circunferenciales.
12. Un aparato de perforación usado para perforar un pozo subterráneo, el aparato de perforación comprende:
- un portador de pistola generalmente tubular;
 - un tubo de carga montado de manera rotatable dentro del portador de pistola; el tubo de carga incluyendo una pluralidad de ranuras que se extienden circunferencialmente;
 - al menos una carga hueca montada en el tubo de carga y operable para perforar el pozo durante la detonación; y
 - un sistema de peso dinámicamente ajustable acoplado con el tubo de carga, el sistema de peso dinámicamente ajustable incluye una pluralidad de pesos discretos que se acoplan al tubo de carga en las ranuras, de manera que la localización circunferencial de los pesos es ajustable a lo largo de las ranuras para ajustar el centro de gravedad del tubo de carga de manera que la gravedad provocará que el tubo de carga rote dentro del portador de pistola para posicionar al menos una carga hueca en una dirección circunferencial en relación con el pozo previo a la perforación.
13. El aparato de perforación mencionado en la reivindicación 12 en donde las ranuras se extienden circunferencialmente entre aproximadamente 90 y 180 grados.
14. El aparato de perforación mencionado en la reivindicación 12 en donde las ranuras adyacentes se extienden en direcciones circunferencialmente opuestas.

15. El aparato de perforación mencionado en la reivindicación 12 en donde los pesos se unen al tubo de carga usando pernos que son selectivamente desplazables dentro de las ranuras.
16. El aparato de perforación mencionado en la reivindicación 12 en donde al
5 menos una carga hueca comprende además una pluralidad de cargas huecas y en donde cada una de las cargas huecas se posiciona en el sostenedor de carga para disparar sustancialmente en la misma dirección circunferencial.
17. El aparato de perforación mencionado en la reivindicación 12 en donde al
10 menos una carga hueca comprende además una pluralidad de cargas huecas y en donde las cargas huecas se posiciona en el sostenedor de carga para disparar en múltiples direcciones circunferenciales.
18. Un método para perforar un pozo subterráneo que comprende las etapas de:
identificar al menos una dirección circunferencial indeseada asociada con un intervalo de perforación en el pozo;
15 ajustar los componentes de un sistema de peso dinámicamente ajustable para cambiar el centro de gravedad de un sostenedor de carga montado de manera rotatable dentro de un portador de pistola;
posicionar el portador de pistola dentro del intervalo de perforación en el pozo;
alineal gravitacionalmente al menos una carga hueca montada en el sostenedor de
20 carga en al menos una dirección circunferencial deseada en relación con el pozo que no se corresponda con al menos una dirección circunferencialmente indeseada; y
disparar al menos una carga hueca para perforar el pozo en al menos una dirección circunferencialmente deseada.
19. El método mencionado en la reivindicación 18 en donde ajustar los
25 componentes de un sistema de peso dinámicamente ajustable comprende además relocalizar los pesos discretos circunferencialmente alrededor del sostenedor de carga.
20. El método mencionado en la reivindicación 19 en donde relocalizar los pesos discretos circunferencialmente alrededor del sostenedor de carga comprende además relocalizar los pesos discretos en relación con las aberturas distribuidas circunferencialmente
30 en el sostenedor de carga.
21. El método mencionado en la reivindicación 19 en donde relocalizar los pesos discretos circunferencialmente alrededor del sostenedor de carga comprende además relocalizar los pesos discretos en relación con las ranuras que se extienden circunferencialmente en el sostenedor de carga.

22. El método mencionado en la reivindicación 18 en donde ajustar los componentes de un sistema de peso dinámicamente ajustable comprende además cambiar la cantidad del material pesado en al menos un tubo que se extiende longitudinalmente.

5 23. El método mencionado en la reivindicación 18 en donde ajustar los componentes de un sistema de peso dinámicamente ajustable comprende además remodelar el material maleable dispuesto dentro del sostenedor de carga.

24. El método mencionado en la reivindicación 18 en donde ajustar los componentes de un sistema de peso dinámicamente ajustable comprende además rotar un tubo de peso en relación con el sostenedor de carga.

10 25. El método mencionado en la reivindicación 18 en donde disparar al menos una carga hueca para perforar el pozo en al menos una dirección circunferencial deseada comprende además disparar una pluralidad de cargas huecas sustancialmente en la misma dirección circunferencial.

15 26. El método mencionado en la reivindicación 18 en donde disparar al menos una carga hueca para perforar el pozo en al menos una dirección circunferencial deseada comprende además disparar una pluralidad de cargas huecas en múltiples direcciones circunferenciales.

SISTEMA Y MÉTODO PARA AJUSTAR DINÁMICAMENTE EL CENTRO DE GRAVEDAD DE UN APARATO DE PERFORACIÓN

5

RESUMEN DE LA DESCRIPCIÓN

Un aparato de perforación (100) usado para perforar un pozo subterráneo. El aparato de perforación (100) incluye un portador de pistola generalmente tubular (106) que tiene un sostenedor de carga (104) montado de manera rotatable dentro del portador de pistola (106). Al menos una carga hueca (102) se monta en el sostenedor de carga (104) y es operable para perforar el pozo durante la detonación. Un sistema de peso dinámicamente ajustable (124) se asocia de manera operable al sostenedor de carga (104). El sistema de peso dinámicamente ajustable (124) es operable para ajustar el centro de gravedad (120) del sostenedor de carga (104) de manera que la gravedad provocará que el sostenedor de carga (104) rote dentro del portador de pistola (106) para posicionar al menos una carga hueca (102) en una dirección circunferencial deseada en relación con el pozo previo a la perforación.

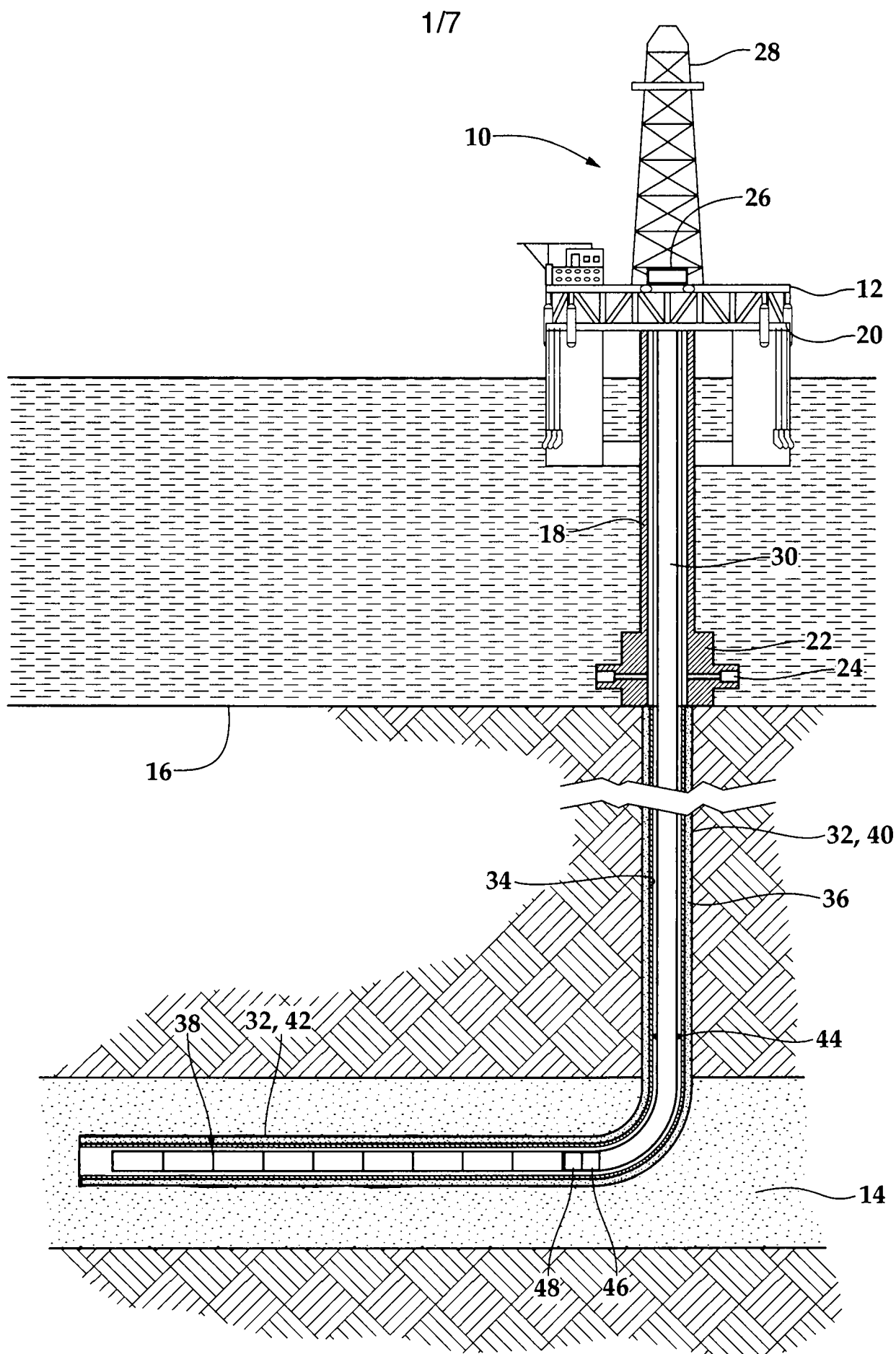


Fig.1

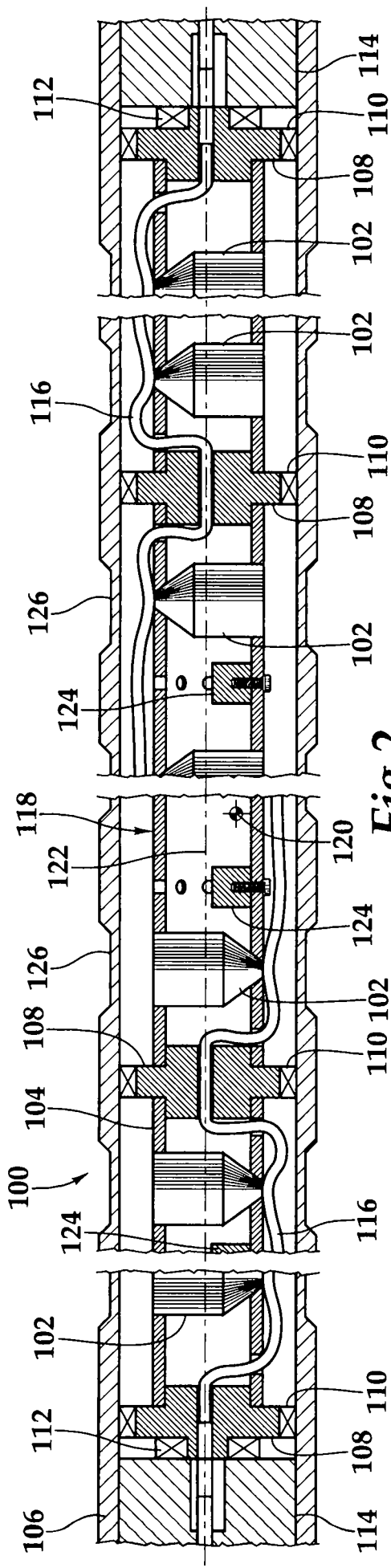


Fig. 2

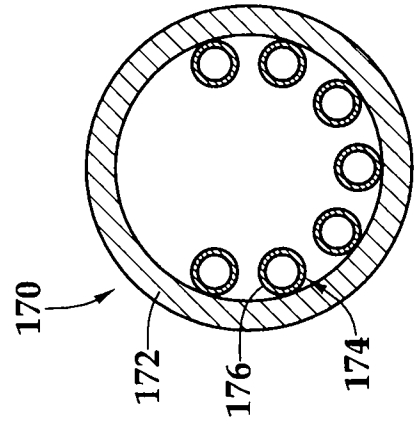


Fig. 5

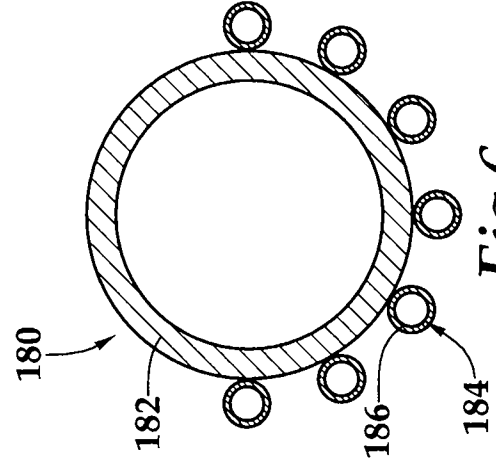


Fig. 6

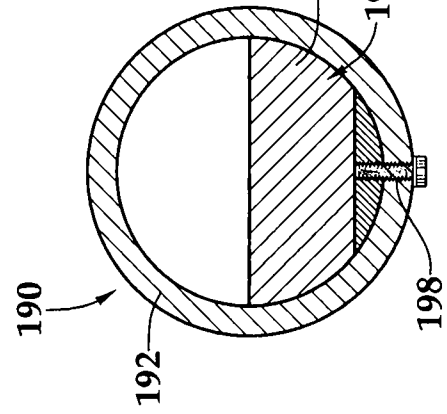


Fig. 7A

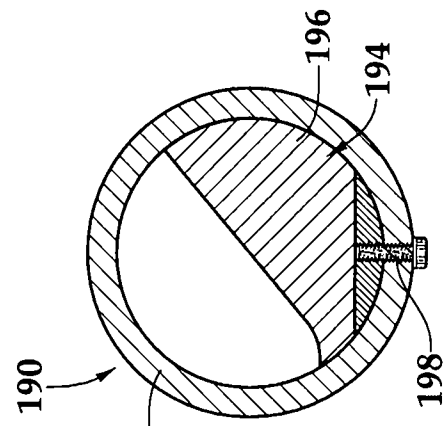


Fig. 7B



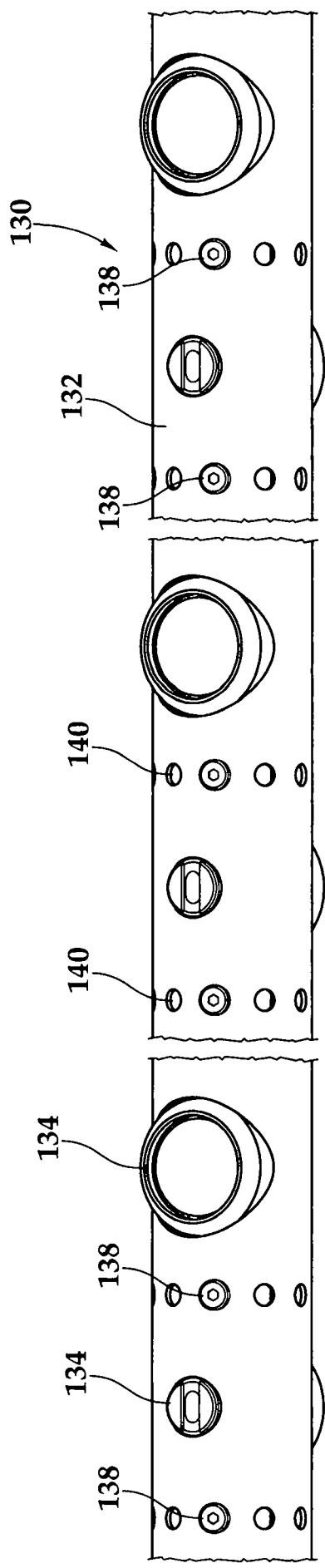


Fig. 3A

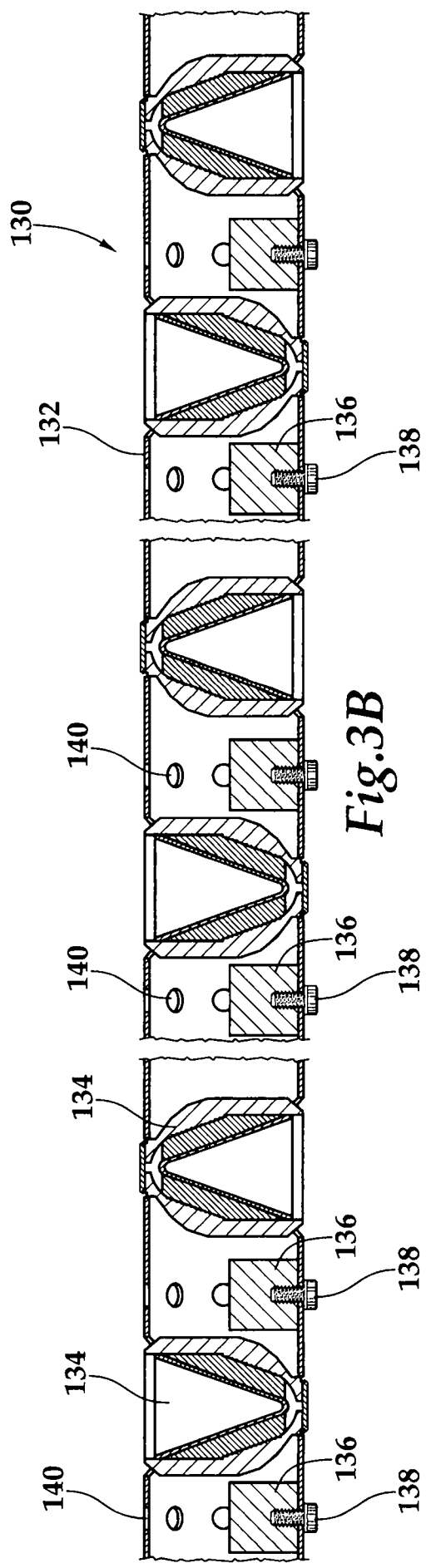


Fig. 3B



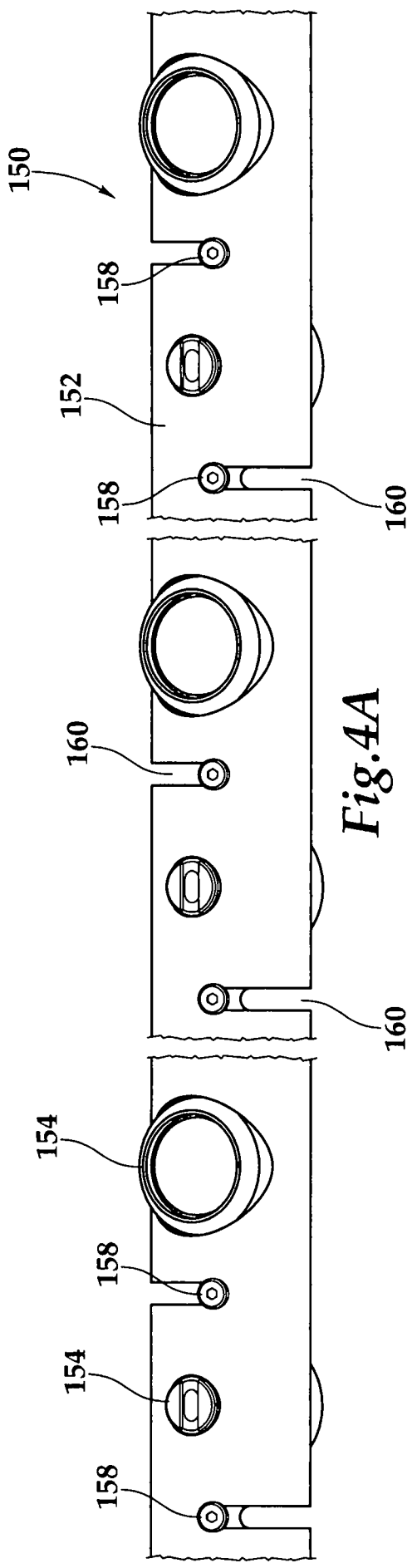


Fig. 4A

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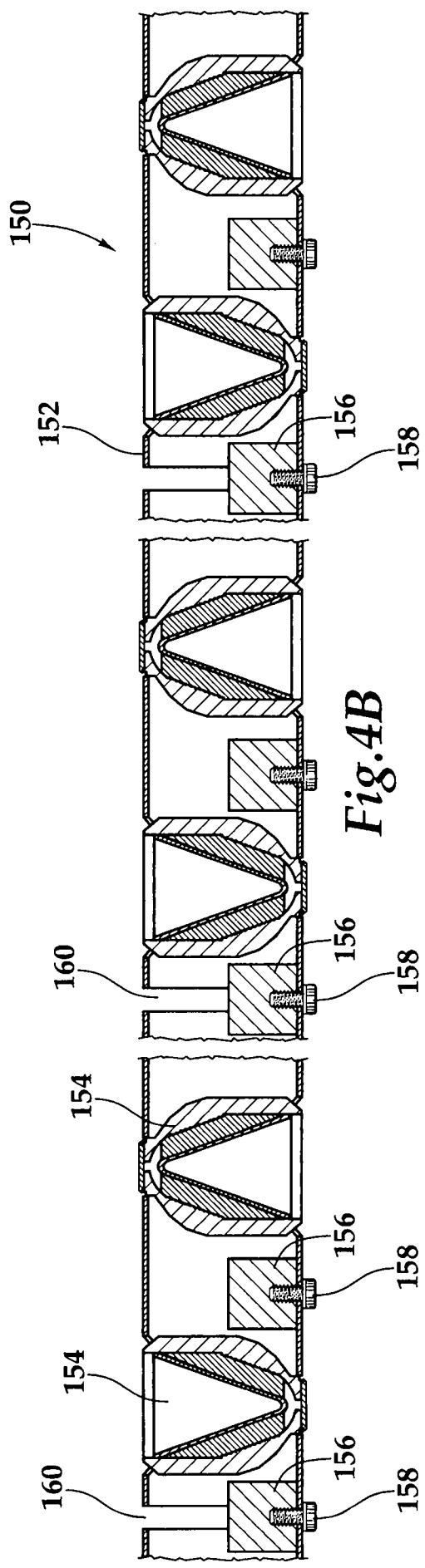


Fig. 4B



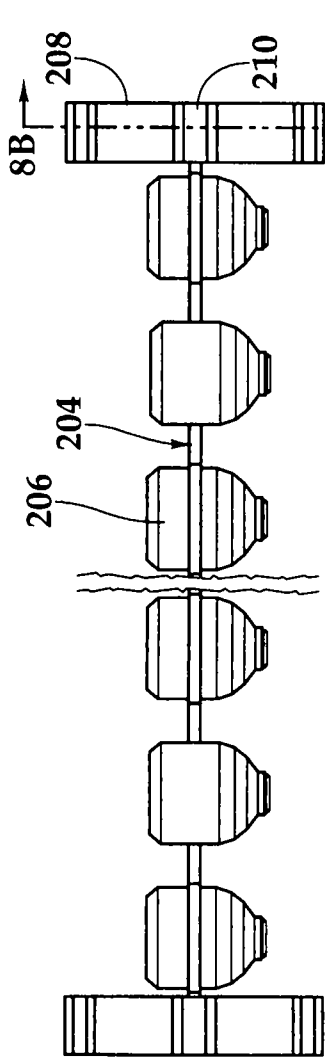


Fig. 8A

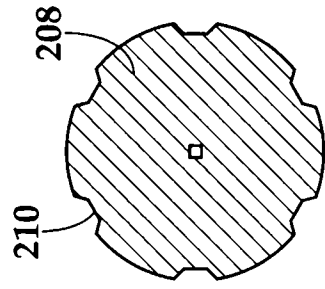


Fig. 8B

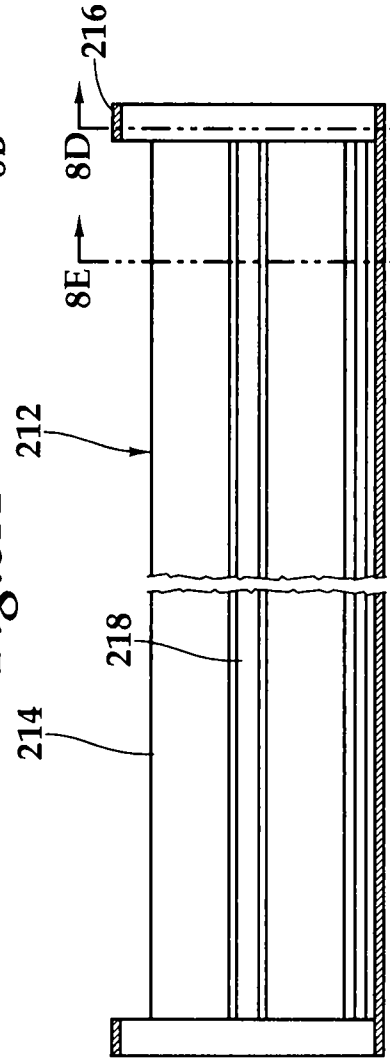


Fig. 8C

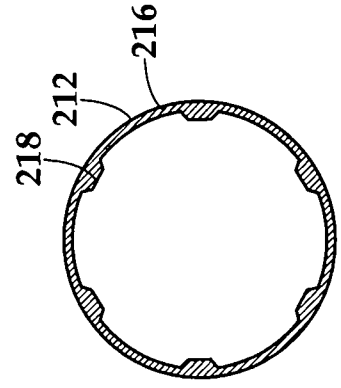


Fig. 8D

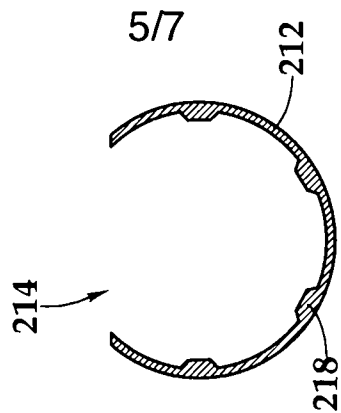


Fig. 8E

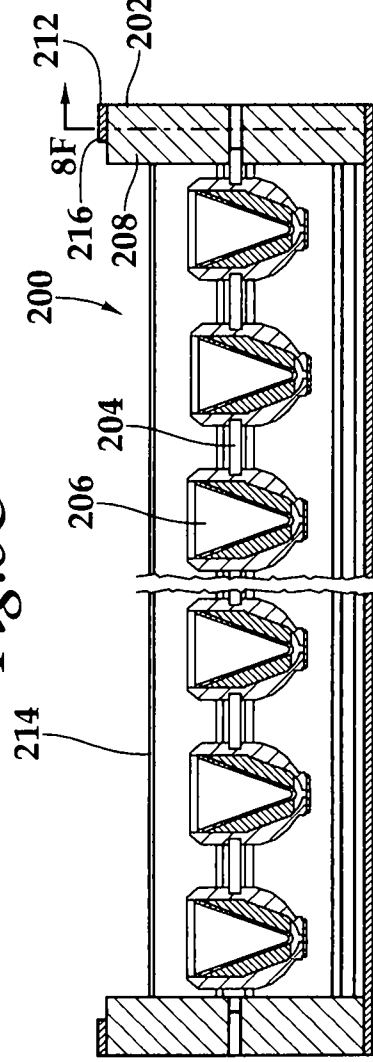


Fig. 8F

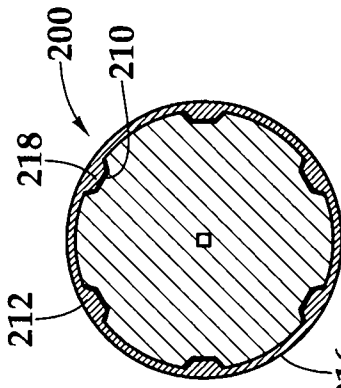
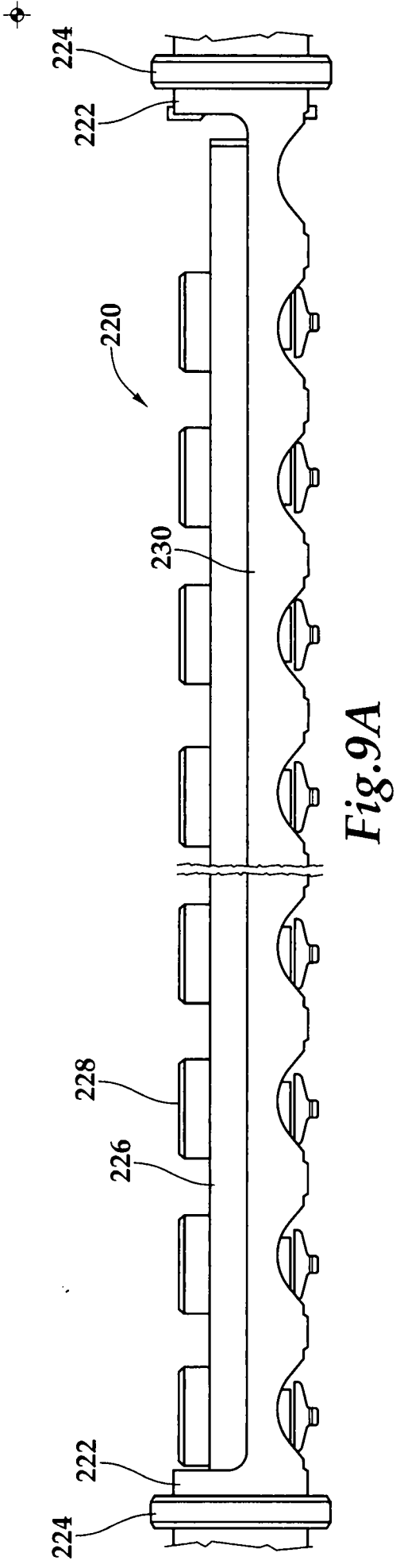
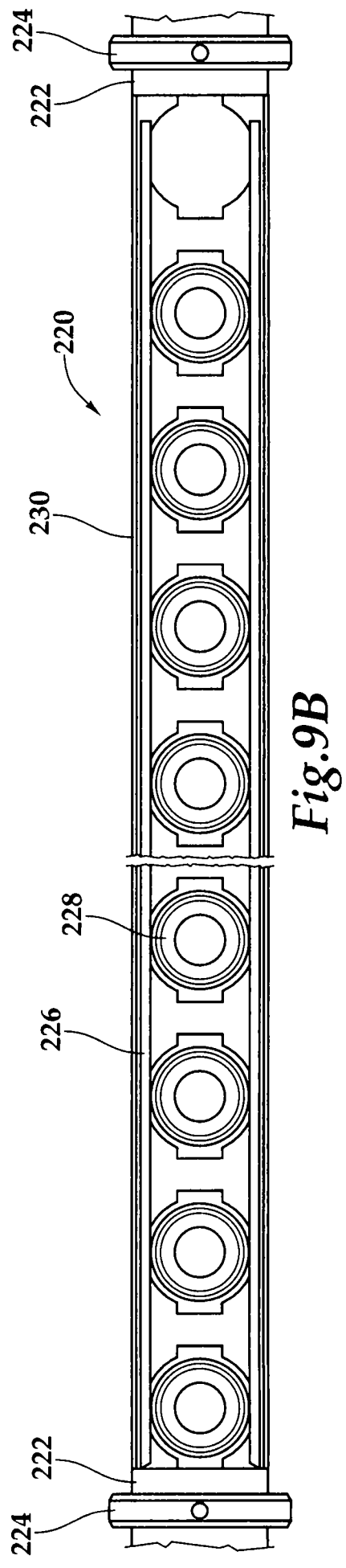


Fig. 8G





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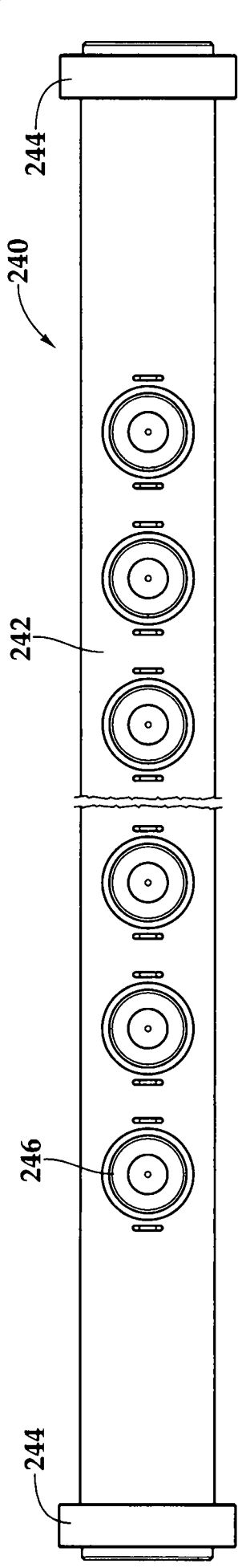


Fig. 10A

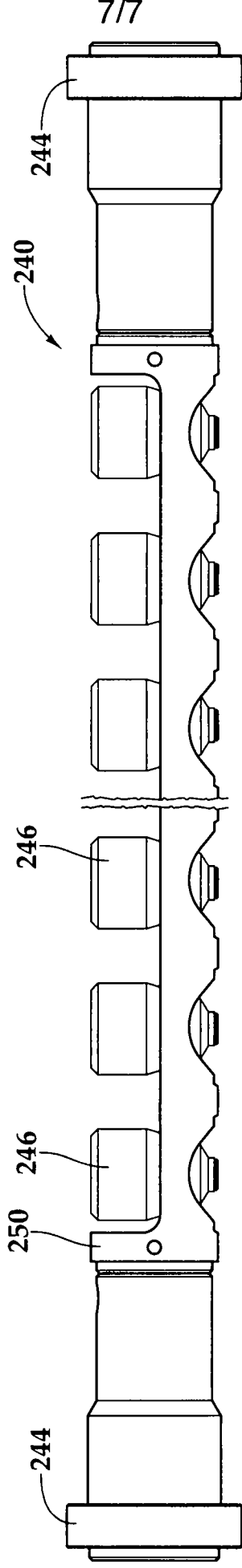


Fig. 10B

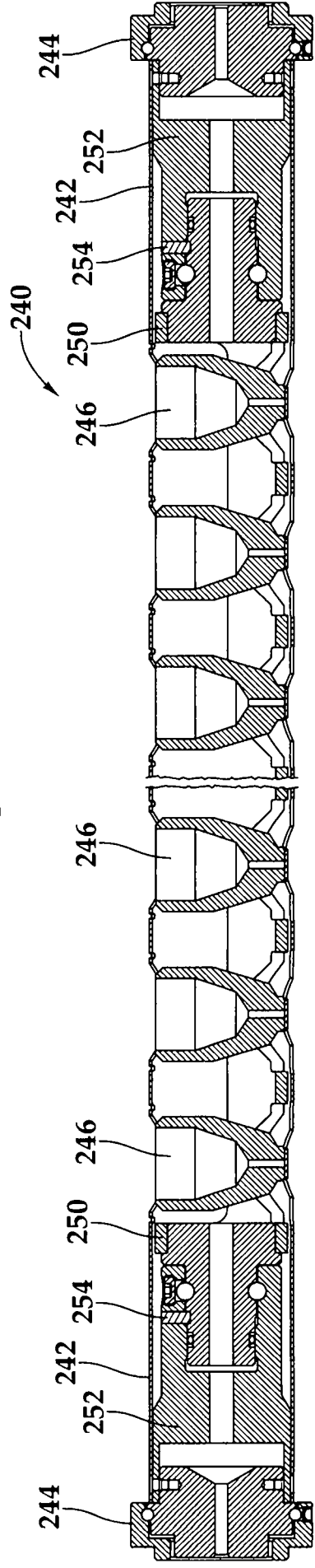


Fig. 10C



**SYSTEM AND METHOD FOR DYNAMICALLY ADJUSTING THE
CENTER OF GRAVITY OF A PERFORATING APPARATUS**

5

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates, in general, to perforating a wellbore that traverses a fluid bearing subterranean formation using shaped charges and, in particular, to an apparatus and
10 method for dynamically adjusting the center of gravity of a perforating apparatus.

BACKGROUND OF THE INVENTION

[0002] Without limiting the scope of the present invention, its background will be described with reference to perforating a subterranean formation with a shaped charge perforating
15 apparatus, as an example.

[0003] After drilling the various sections of a subterranean wellbore that traverses a formation, individual lengths of relatively large diameter metal tubulars are typically secured together to form a casing string that is positioned within the wellbore. This casing string increases the integrity of the wellbore and provides a path for producing fluids from the
20 producing intervals to the surface. Conventionally, the casing string is cemented within the wellbore. To produce fluids into the casing string, hydraulic opening or perforation must be made through the casing string, the cement and a short distance into the formation.

[0004] Typically, these perforations are created by detonating a series of shaped charges located within the casing string that are positioned adjacent to the desired formation.
25 Specifically, one or more charge carriers are loaded with shaped charges that are connected with a detonating device, such as detonating cord. The charge carriers are then connected within a tool string that is lowered into the cased wellbore at the end of a tubing string, wireline, slick line, coil tubing or the like. Once the charge carriers are properly positioned in the wellbore such that the shaped charges are adjacent to the formation to be perforated, the
30 shaped charges are detonated. Upon detonation, the shaped charges create jets that blast through scallops or recesses in the carrier. Each jet creates a hydraulic opening through the casing and the cement and enters the formation forming a perforation.

[0005] It has been found, however, that it is sometimes desirable to perforate a wellbore in a particular direction or range of directions relative to the wellbore. For example, in a deviated,
35 inclined or horizontal well, it is frequently beneficial to form perforations in the upward

direction, the downward direction or both. Attempts have been made to achieve this goal of perforating wells in particular directions. One method of orienting perforating charges downhole requires the charges to be rigidly mounted in a gun carrier so that they are pointed in the desired directions relative to the carrier. The gun carrier is then conveyed into a wellbore and either laterally biased physically to one side of the wellbore so that the gun carrier seeks the lower portion of the wellbore due to gravity, or the gun carrier is rotatably supported with its center of gravity laterally offset relative to the wellbore. This method relies on the gun carrier rotating in the wellbore, so that the gun carrier may be oriented relative to the force of gravity. Frequently, such orienting rotation is unreliable due to friction between the gun carrier and the wellbore, debris in the wellbore or the like.

[0006] More recently, the assignee of the present invention has developed a perforating gun that includes a tubular gun carrier, multiple perforating charges, multiple charge mounting structures and multiple rotating supports. This internally oriented perforating apparatus has successfully provided increased reliability in orienting perforating charges to shoot in the desired directions in a well. In this design, the direction or directions of the perforations is established when the gun is assembly in its manufacturing facility.

[0007] It has been found, however, that in certain installations, it is necessary to avoid shooting in a particular direction or directions. For example, one or more communication conduits or controls lines may extend along the exterior of the casing string. During installation, these conduits commonly become wound around the casing string such that the exact location of these lines can only determined after installation by, for example, logging the well.

[0008] A need has therefore arisen for an apparatus and method operable to achieve reliable downhole orientation of the shaped charges in a perforating apparatus such that the shaped charges shoot in desired directions. In addition, a need has arisen for such an apparatus and method operable to achieve reliable downhole orientation of the shaped charges in a perforating apparatus such that the shaped charges do not shoot in undesired directions.

SUMMARY OF THE INVENTION

[0009] The present invention disclosed herein comprises an apparatus and method for dynamically adjusting the center of gravity of a perforating apparatus. The apparatus and method of the present invention are operable to achieve reliable downhole orientation of shaped charges in a perforating apparatus such that the shaped charges shoot in desired directions. In addition, apparatus and method of the present invention are operable to achieve

reliable downhole orientation of shaped charges in a perforating apparatus such that the shaped charges do not shoot in undesired directions

[0010] In one aspect, the present invention is directed to a perforating apparatus used to perforate a subterranean well. The perforating apparatus includes a generally tubular gun carrier having a charge holder rotatably mounted therein. At least one shaped charge is mounted in the charge holder and is operable to perforate the well upon detonation. A dynamically adjustable weight system is operably associated to the charge holder. The dynamically adjustable weight system is operable to adjust the center of gravity of the charge holder such that gravity will cause the charge holder to rotate within the gun carrier to position the at least one shaped charge in a desired circumferential direction relative to the well prior to perforating.

[0011] In one embodiment, the dynamically adjustable weight system includes a plurality of discrete weights that are individually coupled to the charge holder at a plurality of longitudinal locations. In this embodiment, for each of the longitudinal locations, the charge holder may include a plurality of circumferentially distributed openings such as uniformly distributed openings at between about 15 and 60 degree increments. Alternatively, for each of the longitudinal locations, the charge holder may include a circumferentially extending slot that may extend circumferentially between about 90 and 180 degrees.

[0012] In another embodiment, the dynamically adjustable weight system includes a plurality of longitudinally extending tubes operable to contain a weighted material therein. In a further embodiment, the dynamically adjustable weight system includes weights formed from a malleable material. In yet another embodiment, the dynamically adjustable weight system includes a weight tube that is rotatable relative to the charge holder. In any of these embodiments, the at least one shaped charge may include a plurality of shaped charges that may be positioned in the charge holder to fire in substantially the same circumferential direction or the shaped charges may be positioned in the charge holder to fire in multiple circumferential directions.

[0013] In another aspect, the present invention is directed to a perforating apparatus used to perforate a subterranean well. The perforating apparatus includes a generally tubular gun carrier having a charge tube rotatably mounted therein. The charge tube includes a plurality of circumferentially extending slots. At least one shaped charge is mounted in the charge tube and is operable to perforate the well upon detonation. A dynamically adjustable weight system is coupled to the charge tube. The dynamically adjustable weight system includes a plurality of discrete weights that are coupled to the charge tube at the slots such that the

circumferential location of the weights is adjustable along the length of the slots to adjust the center of gravity of the charge tube such that gravity will cause the charge tube to rotate within the gun carrier to position the at least one shaped charge in a desired circumferential direction relative to the well prior to perforating.

5 [0014] In one embodiment, adjacent slots in the charge tube extend in circumferentially opposite directions. In another embodiment, the weights are attached to the charge tube using bolts that are selectively slidable within the slots.

[0015] In another aspect, the present invention is directed to a method of perforating a subterranean well. The method includes identifying at least one undesired circumferential
10 direction associated with a perforating interval in the well; adjusting components of a dynamically adjustable weight system to change the center of gravity of a charge holder rotatably mounted within a gun carrier; positioning the gun carrier within the perforating interval in the well; gravitationally aligning a least one shaped charge mounted in the charge holder in at least one desired circumferential direction relative to the well that does not
15 correspond with the at least one undesired circumferential direction; and firing the at least one shaped charge to perforate the well in the at least one desired circumferential direction.

[0016] The method may also include relocating discrete weights circumferentially about the charge holder. This may be accomplished by relocating the discrete weights relative to circumferentially distributed openings in the charge holder or relocating the discrete weights
20 relative to circumferentially extending slots in the charge holder. Alternatively, the method may include changing the amount of weighted material in at least one longitudinally extending tube, reshaping malleable material disposed within the charge holder or rotating a weight tube relative to the charge holder.

25 BRIEF DESCRIPTION OF THE DRAWINGS

[0017] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

30 [0018] Figure 1 is a schematic illustration of an offshore oil and gas platform operating a plurality of apparatuses for dynamically adjusting the center of gravity of perforating apparatuses of the present invention;

[0019] Figure 2 is a cross sectional view of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0020] Figures 3A-3B are side and cross sectional views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0021] Figures 4A-4B are side and cross sectional views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0022] Figure 5 is a cross sectional view of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0023] Figure 6 is a cross sectional view of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0024] Figures 7A-7B are a cross sectional views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0025] Figures 8A-8G are various views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0026] Figures 9A-9B are a side and top views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention; and

[0027] Figures 10A-10C are various views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0028] While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention, and do not delimit the scope of the present invention.

[0029] Referring initially to Figure 1, a plurality of apparatuses for dynamically adjusting the center of gravity of perforating apparatuses operating from an offshore oil and gas platform are schematically illustrated and generally designated 10. A semi-submersible platform 12 is centered over a submerged oil and gas formation 14 located below sea floor 16. A subsea conduit 18 extends from deck 20 of platform 12 to wellhead installation 22 including subsea

blow-out preventers 24. Platform 12 has a hoisting apparatus 26 and a derrick 28 for raising and lowering pipe strings such as work string 30.

[0030] A wellbore 32 extends through the various earth strata including formation 14. A casing 34 is cemented within wellbore 32 by cement 36. Work string 30 includes various tools such as a plurality of perforating apparatuses or guns 38. When it is desired to perforate casing 34, work string 30 is lowered through casing 34 until the perforating guns 38 are properly positioned relative to formation 14. Thereafter, the shaped charges within the string of perforating guns 38 are sequentially fired, either in an uphole to downhole or a downhole to uphole direction. Upon detonation, the liners of the shaped charges form jets that create a spaced series of perforations extending outwardly through casing 34, cement 36 and into formation 14, thereby allow fluid communication between formation 14 and wellbore 32.

[0031] In the illustrated embodiment, wellbore 32 has an initial, generally vertical portion 40 and a lower, generally deviated portion 42 which is illustrated as being horizontal. It should be noted, however, by those skilled in the art that the apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention is equally well-suited for use in other well configurations including, but not limited to, inclined wells, wells with restrictions, non-deviated wells, multilateral wells and the like. In addition, even though an offshore operation has been depicted in figure 1, the apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention is equally well-suited for use in onshore operations.

[0032] Work string 30 includes a packer 44 that may be sealingly engaged with casing 34 and is illustrated in the vertical portion 40 of wellbore 32. At the lower end of work string 30 is the gun string including the plurality of perforating guns 38, a ported nipple 46 and a fire head 48. In the illustrated embodiment, perforating guns 38 include internal orientation features which allow for reliable rotation of the charge tube within the gun carrier as described in United States Patent No. 6,595,290 issued to Halliburton Energy Services, Inc. on July 22, 2003, which is hereby incorporated by reference for all purposes.

[0033] Referring now to figure 2, therein is depicted a perforating apparatus that includes an apparatus for dynamically adjusting the center of gravity of the perforating apparatus of the present invention that is generally designated 100. In the following description of apparatus 100 as well as the other apparatuses and methods described herein, directional terms such as "above", "below", "upper", "lower" and the like are used for convenience in referring to the illustrations as it is to be understood that the various embodiments of the invention may be

used in various orientations such as inclined, inverted, horizontal, vertical and the like and in various configurations, without departing from the principles of the invention.

5 [0034] Gun 100 includes a plurality of shaped charges 102 that are securably mounted in a charge holder that is depicted as charge tube 104. Charge tube 104 is rotatably mounted within gun carrier 106. Preferably, charge tube 104 is made from cylindrical tubing, but it should be understood that it is not necessary for charge tube 104 to be tubular or have a cylindrical shape in keeping with the principles of the invention. Charge tube 104 includes multiple supports 108 that allow charge tube 104 to rotate within gun carrier 106. This manner of rotatably supporting charge tube 104 prevents charges 102 or any other portion of
10 charge tube 104 from contacting the interior of gun carrier 106.

[0035] Each of the supports 108 includes rolling elements or bearings 110 contacting the interior of gun carrier 106. For example, bearings 110 could be ball bearings, roller bearings, plain bearings or the like. Bearings 110 enable supports 108 to suspend charge tube 104 in gun carrier 106 and permit rotation thereof. In addition, optional thrust bearings 112 may be
15 positioned between each end of charge tube 104 and gun carrier 106 such that thrust bearings 112 contact devices 114 attached at each end of gun carrier 106. Each device 114 may be tandems that are used to couple two guns to each other, a bull plug used to terminate a gun string, a firing head, or any other type of device which may be attached to gun carrier 106. As with bearings 110 described above, thrust bearings 112 may be any type of bearings.
20 Thrust bearings 112 support charge tube 104 against axial loading within gun carrier 106, while permitting charge tube 104 to rotate within gun carrier 106.

[0036] Charge tube 104, charges 102 and other portions of gun 100 supported in gun carrier 106 by the supports 108 including, for example, a detonating cord 116 extending to each of the charges and portions of the supports themselves, are parts of an overall rotating assembly
25 118. By offsetting a center of gravity 120 of assembly 118 relative to a longitudinal rotational axis 122 of bearings 110, assembly 118 is biased by gravity to rotate to a specific position in which the center of gravity 120 is located directly below the rotational axis 122.

[0037] Assembly 118 may, due the construction of the various elements thereof, initially have the center of gravity 120 in a desired position relative to charges 102. However, to
30 ensure that charges 102 are directed to shoot in respective predetermined directions, the center of gravity 120 may be repositioned using a dynamically adjustable weight system that is depicted as weights 124. In the illustrated embodiment, on the left side of figure 2, weights 124 are added to assembly 118 to direct the charges 102 to shoot upward, while on the right side of figure 2, weights 124 are added to assembly 118 to direct the charges 102 to shoot

downward. As discussed in greater detail below, weights 124 may be otherwise positioned to direct the charges 102 to shoot in any desired direction, or combination of directions and to avoid shooting in undesired directions.

[0038] Gun carrier 106 is provided with reduced wall thickness portions 126, which extend circumferentially about carrier 106 outwardly overlying each of the charges 102. Thus, as the charges 102 rotate within carrier 106, they remain directed to shoot through the portions 126. The reduced wall thickness portions 126 may be formed on carrier 106 by rolling, forging, lathe cutting or any other suitable technique.

[0039] Referring next to figures 3A and 3B, therein are depicted side and cross sectional views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 130. Apparatus 130 includes a charge holder depicted as charge tube 132 which houses a plurality of shaped charges 134. In the illustrated embodiment, shaped charges 134 are configured in a 180 degree phased pattern, however, those skilled in the art will appreciate that any number of alternative phased patterns of the shaped charges are possible and are considered within the scope of the present invention.

[0040] Apparatus 130 also includes a dynamically adjustable weight system depicted as weights 136. In the illustrated embodiment, each of the weights 136 includes a threaded portion that is operable to receive therein a complementary threaded bolt 138. Weights 136 are accordingly attached to charge tube 132 by passing the shaft portion of a bolt 138 through one of a plurality of openings 140 in charge tube 132 and then rotatably coupling that bolt 138 to one of the weights 136. As illustrated, each longitudinal location of charge tube 132 that is designed to receive a weight 136 has eight openings 140 that are circumferentially spaced apart at 45 degree increments. It should be understood by those skilled in the art, however, that any number of openings having any desired circumferentially spacing both uniform and nonuniform is possible and is considered within the scope of the present invention, so long as the structural integrity of charge tube 132 is maintained. For example, it may be desirable to have openings that are circumferentially spaced uniformly around a charge tube at between about 15 and about 60 degree increments.

[0041] As used herein, the term dynamically adjustable refers to the ability to change the center of gravity of a perforating apparatus in the field as opposed to only as the perforating apparatus is manufactured. This ability provides the versatility to make adjustments to apparatus 130 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line

disposed to the exterior of the casing string. Continuing with this example, if one or more control lines are position to the exterior of the casing string, it is imperative to avoid causing damage to the control lines during the perforating process. As these control lines commonly take on a spiral configuration around the casing string during installation, the actual location of the control lines must be determined prior to perforating the well by, for example, logging the well. Once the circumferential location of the control lines is known for each depth of the well, the present invention allows field personnel to custom design the perforating gun string such that the control lines can be avoided and the well can be perforated in the desired directional orientations.

[0042] In the illustrated embodiment, this is accomplished by repositioning the weights 136 relative to any one of the respective openings 140 circumferentially spaced around charge tube 132. For example, if charge tube 132 were installed within a gun carrier as configured in figure 3B and deployed in a horizontal well, weights 136 would cause charge tube 132 to rotate to the position depicted in figure 3B wherein shaped charges 134 would fire at 0 and 180 degrees in the well. If weights 136 were each moved to the next adjacent position, shaped charges 134 would fire at 45 and 225 degrees in the well. Likewise, if weights 136 were each moved again to the next adjacent position, shaped charges 134 would fire at 90 and 270 degrees in the well. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0043] Even though figures 3A-3B have depicted apparatus 130 as having one weight positioned between adjacent shaped charge, it should be understood by those skilled in the art that no particular relationship is required between the number of weights and the number of shaped charges in a given perforating apparatus. The number and configuration of the weights and shaped charges will vary based upon factors such as the desired shots per foot, the diameter of the charge tube, the explosive mass of the charges, the size of the weights, the spacing between charges and the like. The important factor is that the center of gravity is dynamically adjustable to cause the charge tube to rotate within the gun carrier to the desired position.

[0044] Referring next to figures 4A and 4B, therein are depicted side and cross sectional views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 150. Apparatus 150 includes a charge holder depicted as charge tube 152 which houses a plurality of shaped charges 154. In the illustrated embodiment, shaped charges 154 are configured in a 180 degree phased

pattern, however, those skilled in the art will appreciate that any number of alternative phased patterns of the shaped charges are possible and are considered within the scope of the present invention.

5 [0045] Apparatus 150 also includes a dynamically adjustable weight system depicted as weights 156. In the illustrated embodiment, each of the weights 156 includes a threaded portion that is operable to receive therein a complementary threaded bolt 158. Weights 156 are accordingly attached to charge tube 152 by passing the shaft portion of a bolt 158 through a slot 160 in charge tube 152 and then rotatably coupling that bolt 158 to one of the weights 156. As illustrated, each longitudinal location of charge tube 152 that is designed to receive a weight 156 has a slot 160 that circumferentially traverses 180 degrees of charge tube 152. Adjacent slots 160 of apparatus 150 are configured such that they extend on opposite sides of charge tube 152. This design enhances the structural integrity of charge tube 152 and allows for infinite variability in the center of gravity of apparatus 150. In certain implementations, weights 156 may be placed in each of the slots 160. In other implementations, it may be desirable to have weights 156 in every other slot 160 such that each of the weights 156 can be positioned at the same circumferential position. It should be understood by those skilled in the art that slots 160 could have other circumferential orientations and could have other relative spacing arrangement, both uniform and nonuniform, without departing from the principles of the present invention, so long as the structural integrity of charge tube 152 is maintained.

20 [0046] As discussed above, the combination of slots 160 and weights 156 allow for dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 150 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by circumferentially repositioning the weights 156 along slots 160 by loosening bolts 158, sliding the weights 156 to the desired circumferential position and resecuring the weights 156 to charge tube 152 with the bolts 158. If charge tube 152 were installed within a gun carrier as loaded in figure 4B and deployed in a horizontal well, weights 156 would cause charge tube 152 to rotate to the position depicted in figure 4B wherein shaped charges 154 would fire at 0 and 180 degrees in the well. Repositioning of the weights 156 along slots 160, as described above, would allow for firing in any desired circumferential directions. Accordingly, the directions the shaped charges will perforate the

well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0047] Referring next to figure 5, therein is depicted a cross sectional view of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 170. Apparatus 170 includes a charge holder depicted as charge tube 172 which houses a plurality of shaped charges (not pictured). Apparatus 170 also includes a dynamically adjustable weight system 174 that is depicted a plurality of tubes 176. Tubes 176 extend at least partially longitudinally within charge tube 172 and are operable to contain a weighted material such as a fluid or a solid. As illustrated, apparatus 170 includes seven tubular tubes 176 that are circumferentially distributed within charge tube 172 at 30 degree increments. It should be understood by those skilled in the art that tubes 176 could have other circumferential orientations, both uniform and nonuniform, within charge tube 172 without departing from the principles of the present invention. Likewise, even though tubes 176 are depicted as having a tubular cross section, tubes 176 could alternatively have other cross sections including, but not limited to, oval cross sections, rectangular cross sections, arc shaped cross sections and the like. In addition, those skilled in the art will recognize that not all of tubes 176 need to have the same cross section or be of the same size.

[0048] In operation, dynamically adjustable weight system 174 of apparatus 170 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 170 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by adding or reducing the weight within tubes 176 by, for example, adding or removing a fluid such as water from tubes 176. As the weight is adjusted in the various tubes 176, the desired downhole rotation of charge tube 172 can be achieved. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0049] Referring next to figure 6, therein is depicted a cross sectional view of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 180. Apparatus 180 includes a charge holder depicted as charge tube 182 which houses a plurality of shaped charges (not pictured). Apparatus 180 also includes a dynamically adjustable weight system 184 that is depicted a plurality of tubes

186. Tubes 186 extend at least partially longitudinally along the exterior of charge tube 182 and are operable to contain a weighted material such as a fluid or a solid. As illustrated, apparatus 180 includes seven tubular tubes 186 that are circumferentially distributed within charge tube 182 at 30 degree increments. It should be understood by those skilled in the art that tubes 186 could have other circumferential orientations, both uniform and nonuniform, within charge tube 182 without departing from the principles of the present invention. Likewise, even though tubes 186 are depicted as having a tubular cross section, tubes 186 could alternatively have other cross sections including, but not limited to, oval cross sections, rectangular cross sections, arc shaped cross sections and the like. In addition, those skilled in the art will recognize that not all of tubes 186 need to have the same cross section or be of the same size.

[0050] In operation, dynamically adjustable weight system 184 of apparatus 180 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 180 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by adding or reducing the weight within tubes 186 by, for example, adding or removing a fluid such as water from tubes 186. As the weight is adjusted in the various tubes 186, the desired downhole rotation of charge tube 182 can be achieved. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0051] Even though figures 5 and 6 have depicted tubes located respectively inside and outside of a charge tube that are operable to receive a weighted material therein, those skilled in the art should recognize that alternate configurations could also be used and would be considered within the scope of the present invention including, but not limited to, forming one or more passageways in the wall of the charge tube or similar tubular operable to receive a weighted material therein.

[0052] Referring next to figures 7A and 7B, therein is depicted cross sectional views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 190. Apparatus 190 includes a charge holder depicted as charge tube 192 which houses a plurality of shaped charges (not pictured). Apparatus 190 also includes a dynamically adjustable weight system 194 that is depicted as malleable weight members 196 that may be formed from a metal such as lead or a polymer.

Malleable weight members 196 may extend at least partially longitudinally along the interior of charge tube 192 or may be discrete weight elements similar to weights 136 and 156 described above. As illustrated, each malleable weight member 196 is coupled to charge tube 192 using one or more bolts 198. In operation, dynamically adjustable weight system 194 of apparatus 190 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 190 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by applying pressure or force to the malleable material that forms malleable weight members 196 using, for example, an adjustment tool that is sized to extend into charge tube 192. The location of at least a portion of the mass of malleable weight members 196 can then be adjusted, as seen in a comparison of figures 7A and 7B, such that the desired downhole rotation of charge tube 192 can be achieved. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0053] Referring next to figures 8A-8G, therein are depicted various views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 200. When assembled, apparatus 200 forms a rotating assembly 202 that is rotatably mounted in a gun carrier in a manner described above. Apparatus 200 includes a charge holder 204 that supports a plurality of shaped charges 206. Charge holder 204 is coupled to end plates 208. Each end plate 208 includes a plurality of notches 210 that are illustrated as being positioned circumferentially around end plates 208 at 60 degree increments, however, those skilled in the art will recognize that notches 210 could have alternate configurations including having different circumferential spacing. In addition, depending upon the length of charge holder 204, it may be desirable to have additional structures that are similar to end plates 208 positioned at intermediate locations along charge holder 204 between certain shaped charges 206. Apparatus 200 also includes a dynamically adjustable weight system depicted as weight tube 212. Weight tube 212 is formed from a substantially tubular member having a window 214, as best seen in figure 8E. In the illustrated embodiment, window 214 extends about 120 degrees circumferentially around weight tube 212, however, those skilled in the art will recognize that window 214 could have alternate configurations including having a different circumferential width or multiple

window sections circumferential distributed around weight tube 212. Weight tube 212 includes circumferential end sections 216 that are sized to closely receive end plates 208. Weight tube 212 includes a plurality of rails 218 that are designed to mesh with notches 210 of end plates 208.

5 **[0054]** In operation, the dynamically adjustable weight system of apparatus 200 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 200 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to
10 the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by inserting charge holder 204 into weight tube 212 such that shaped charges 206 are oriented in the desired direction. For example, if charge holder 204 were installed within weight tube 212 as shown in figure 8F and deployed in a horizontal well, weight tube 212 would cause rotating assembly 202 to rotate to the position depicted in
15 figure 8F wherein shaped charges 206 would fire at 0 degrees in the well. If charge holder 204 was rotated 60 degrees in either direction to realign rails 218 and notches 210, shaped charges 206 would fire at either 60 degrees or 300 degrees in the well. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

20 **[0055]** Referring next to figures 9A-9B, therein are depicted side and top views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 220. When assembled, apparatus 220 forms a rotating assembly 222 that is rotatably mounted in a gun carrier in a manner described above via bearings 224. Apparatus 220 includes a charge holder 226 that supports a plurality of
25 shaped charges 228. Apparatus 220 also includes a dynamically adjustable weight system depicted as weight tube 230. Weight tube 230 is formed from a partially tubular member. Charge holder 226 is selectively rotatable mounted within weight tube 230 such that charge holder 226 may be rotated about 120 degrees circumferentially within weight tube 230. In operation, the dynamically adjustable weight system of apparatus 220 allows field personnel
30 to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 220 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated

embodiment, this is accomplished by selectively releasing a connection such as a pin, a set screw or the like between charge holder 226 and weight tube 230 then rotating charge holder 226 such that shaped charges 228 are oriented in the desired direction. For example, if charge holder 226 was installed within weight tube 230 as shown in figure 9A and deployed in a horizontal well, weight tube 230 would cause rotating assembly 222 to rotate to the position depicted in figure 9A wherein shaped charges 228 would fire at 0 degrees in the well. If another circumferential direction is desired, however, charge holder 226 may be incrementally adjusted in certain embodiments or infinitely adjusted in other embodiments to any position between the locations of maximum travel which have been described above as approximately 60 degrees from vertical in either direction in the illustrated embodiment. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0056] Referring next to figures 10A-10C, therein are depicted various views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 240. Apparatus 240 includes a charge holder depicted as a charge tube 242 that is rotatably mounted in a gun carrier in a manner described above via bearings 244, as best seen in figures 10A and 10C. Charge tube 242 supports a plurality of shaped charges 246. Apparatus 240 also includes a dynamically adjustable weight system depicted as weight tube 250, as best seen in figures 10B and 10C. Weight tube 250 is formed from a partially tubular member. Weight tube 250 is rotatable mounted within a swivel member 252 that is mounted within charge tube 242 such that weight tube 250 may be rotated about 120 degrees circumferentially within charge tube 242. One or more coupling members depicted as pins 254 are used to selectively prevent rotation of weight tube 250 relative to swivel member 252. In operation, the dynamically adjustable weight system of apparatus 240 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 240 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by selectively releasing the connection, such as pins 254, between weight tube 250 and swivel member 252 then rotating weight tube 250 relative to swivel member 252 such that weight tube 250 is positioned in the desired orientation relative to shaped charges 246. For example, if weight tube 250 was installed relative to shaped charges 246 as shown in figures 10B-10C and deployed in a

horizontal well, weight tube 250 would cause charge tube 242 to rotate to the position depicted in figures 10B-10C wherein shaped charges 246 would fire at 0 degrees in the well. If another circumferential direction is desired, however, weight tube 250 may be incrementally adjusted in certain embodiments or infinitely adjusted in other embodiments to
5 any position between the locations of maximum travel which have been described above as approximately 60 degrees from vertical in either direction in the illustrated embodiment. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0057] While this invention has been described with reference to illustrative embodiments,
10 this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention will be apparent to persons skilled in the art upon reference to the description. It is, therefore, intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A perforating apparatus used to perforate a subterranean well, the perforating apparatus comprising:

a generally tubular gun carrier;

5 a charge holder rotatably mounted within the gun carrier;

at least one shaped charge mounted in the charge holder and operable to perforate the well upon detonation; and

a dynamically adjustable weight system operably associated with the charge holder, the dynamically adjustable weight system operable to adjust the center of gravity of the charge holder such that gravity will cause the charge holder to rotate within the gun carrier to position the at least one shaped charge in a desired circumferential direction relative to the well prior to perforating.

2. The perforating apparatus as recited in claim 1 wherein the dynamically adjustable weight system further comprises a plurality of discrete weights that are individually coupled to the charge holder at a plurality of longitudinal locations.

3. The perforating apparatus as recited in claim 2 wherein, for each of the longitudinal locations, the charge holder includes a plurality of circumferentially distributed openings.

4. The perforating apparatus as recited in claim 3 wherein the circumferentially distributed openings are uniformly distributed at between about 15 and about 60 degree increments.

5. The perforating apparatus as recited in claim 2 wherein, for each of the longitudinal locations, the charge holder includes a circumferentially extending slot.

6. The perforating apparatus as recited in claim 5 wherein the slots extend circumferentially between about 90 and 180 degrees.

7. The perforating apparatus as recited in claim 1 wherein the dynamically adjustable weight system further comprises a plurality of longitudinally extending tubes operable to contain a weighted material therein.

8. The perforating apparatus as recited in claim 1 wherein the dynamically adjustable weight system further comprises weights formed from a malleable material.

9. The perforating apparatus as recited in claim 1 wherein the dynamically adjustable weight system further comprises a weight tube that is rotatable relative to the charger holder.

10. The perforating apparatus as recited in claim 1 wherein the at least one shaped charge further comprises a plurality of shaped charges and wherein each of the shaped charges is positioned in the charge holder to fire in substantially the same circumferential direction.

11. The perforating apparatus as recited in claim 1 wherein the at least one shaped charge further comprises a plurality of shaped charges and wherein the shaped charges are positioned in the charge holder to fire in multiple circumferential directions.

12. A perforating apparatus used to perforate a subterranean well, the perforating apparatus comprising:

a generally tubular gun carrier;

5 a charge tube rotatably mounted within the gun carrier, the charge tube including a plurality of circumferentially extending slots;

at least one shaped charge mounted in the charge tube and operable to perforate the well upon detonation; and

10 a dynamically adjustable weight system coupled to the charge tube, the dynamically adjustable weight system including a plurality of discrete weights that are coupled to the charge tube at the slots, such that the circumferential location of the weights is adjustable along the length of the slots to adjust the center of gravity of the charge tube such that gravity will cause the charge tube to rotate within the gun carrier to position the at least one shaped charge in a desired circumferential direction relative to the well prior to perforating.

15 13. The perforating apparatus as recited in claim 12 wherein the slots extend circumferentially between about 90 and 180 degrees.

14. The perforating apparatus as recited in claim 12 wherein adjacent slots extend in circumferentially opposite directions.

20

15. The perforating apparatus as recited in claim 12 wherein the weights are attached to the charge tube using bolts that are selectively slidable within the slots.

25 16. The perforating apparatus as recited in claim 12 wherein the at least one shaped charge further comprises a plurality of shaped charges and wherein each of the shaped charges is positioned in the charge holder to fire in substantially the same circumferential direction.

30 17. The perforating apparatus as recited in claim 12 wherein the at least one shaped charge further comprises a plurality of shaped charges and wherein the shaped charges are positioned in the charge holder to fire in multiple circumferential directions.

18. A method of perforating a subterranean well comprising the steps of:
identifying at least one undesired circumferential direction associated with a
perforating interval in the well;
adjusting components of a dynamically adjustable weight system to change the center
5 of gravity of a charge holder rotatably mounted within a gun carrier;
positioning the gun carrier within the perforating interval in the well;
gravitationally aligning at least one shaped charge mounted in the charge holder in at
least one desired circumferential direction relative to the well that does not correspond with
the at least one undesired circumferential direction; and
10 firing the at least one shaped charge to perforate the well in the at least one desired
circumferential direction.

19. The method as recited in claim 18 wherein adjusting components of a
dynamically adjustable weight system further comprises relocating discrete weights
15 circumferentially about the charge holder.

20. The method as recited in claim 19 wherein relocating discrete weights
circumferentially about the charge holder further comprises relocating the discrete weights
relative to circumferentially distributed openings in the charge holder.

21. The method as recited in claim 19 wherein relocating discrete weights
circumferentially about the charge holder further comprises relocating the discrete weights
relative to circumferentially extending slots in the charge holder.

22. The method as recited in claim 18 wherein adjusting components of a
dynamically adjustable weight system further comprises changing the amount of weighted
material in at least one longitudinally extending tube.

23. The method as recited in claim 18 wherein adjusting components of a
30 dynamically adjustable weight system further comprises reshaping malleable material
disposed within the charge holder.

24. The method as recited in claim 18 wherein adjusting components of a dynamically adjustable weight system further comprises rotating a weight tube relative to the charge holder.

5 25. The method as recited in claim 18 wherein firing the at least one shaped charge to perforate the well in the at least one desired circumferential direction further comprises firing a plurality of shaped charges in substantially the same circumferential direction.

10 26. The method as recited in claim 18 wherein firing the at least one shaped charge to perforate the well in the at least one desired circumferential direction further comprises firing a plurality of shaped charges in multiple circumferential directions.

SYSTEM AND METHOD FOR DYNAMICALLY ADJUSTING THE CENTER OF GRAVITY OF A PERFORATING APPARATUS

ABSTRACT OF THE DISCLOSURE

5 A perforating apparatus (100) used to perforate a subterranean well. The perforating apparatus (100) includes a generally tubular gun carrier (106) and a charge holder (104) rotatably mounted within the gun carrier (106). At least one shaped charge (102) is mounted in the charge holder (104) and is operable to perforate the well upon detonation. A dynamically adjustable weight system (124) is operably associated to the charge holder (104).
10 The dynamically adjustable weight system (124) is operable to adjust the center of gravity (120) of the charge holder (104) such that gravity will cause the charge holder (104) to rotate within the gun carrier (106) to position the at least one shaped charge (102) in a desired circumferential direction relative to the well prior to perforating.

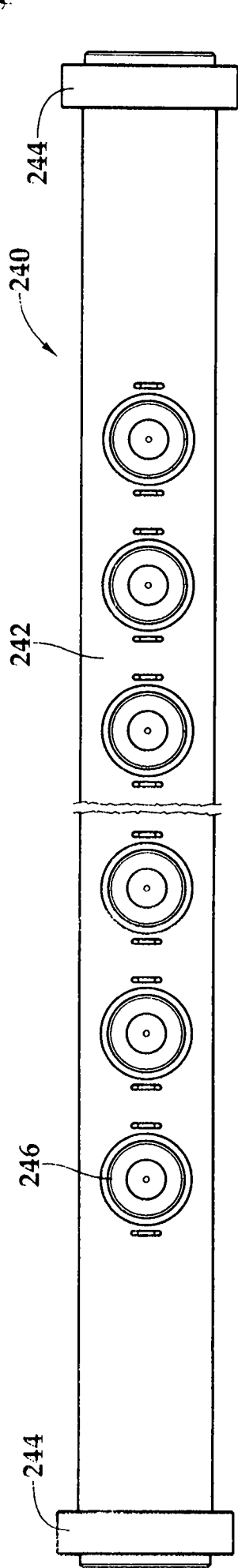


Fig. 10A

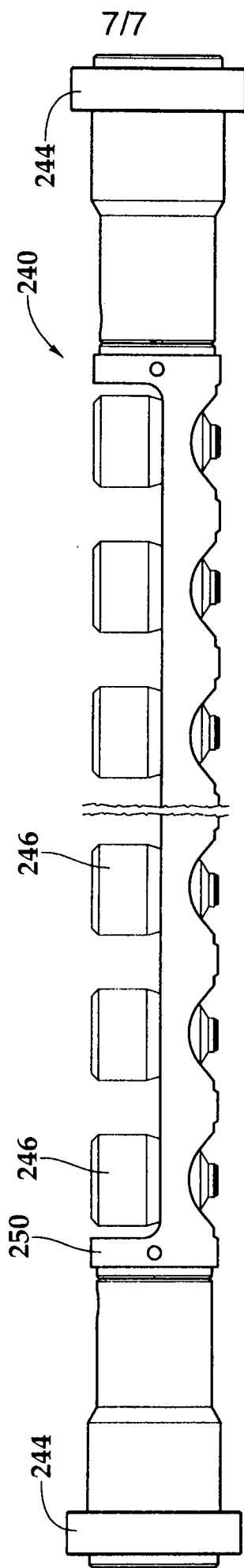


Fig. 10B

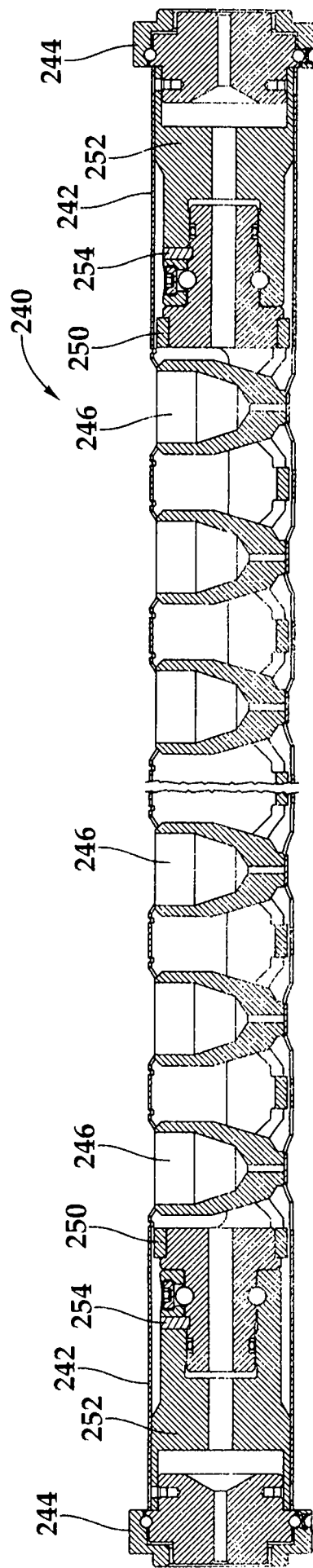


Fig. 10C



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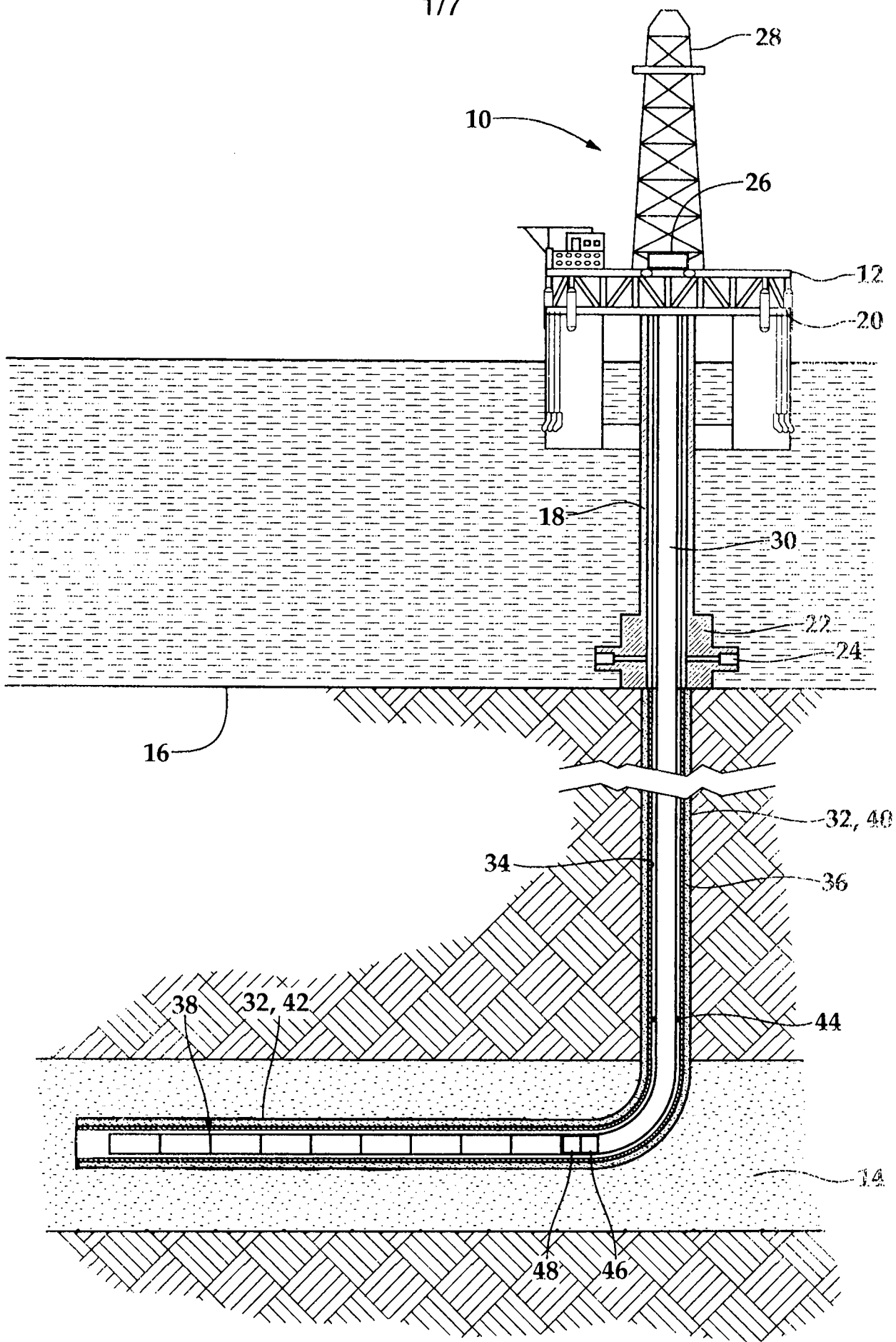


Fig.1

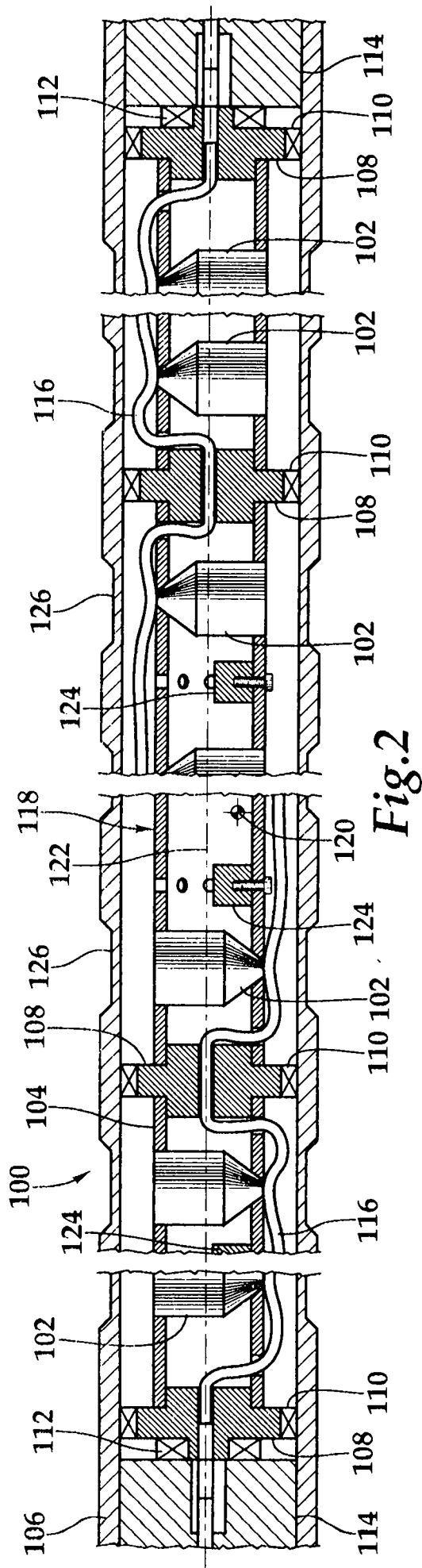


Fig. 2

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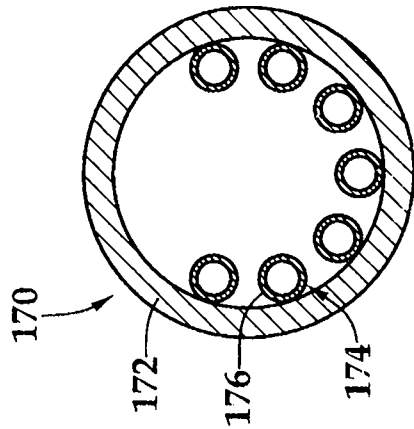


Fig. 5

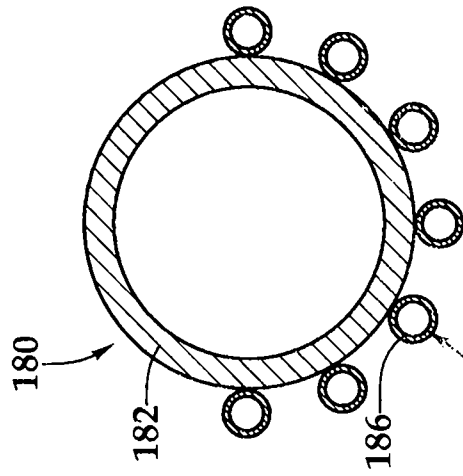


Fig. 6

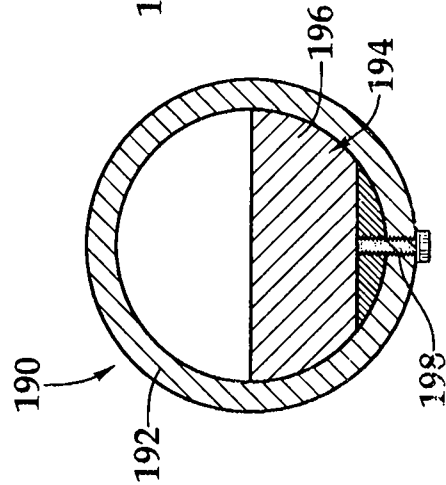


Fig. 7A

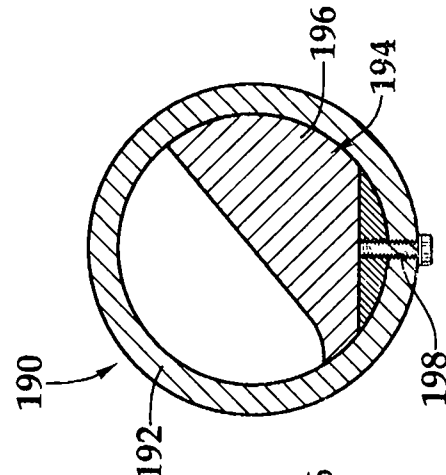


Fig. 7B

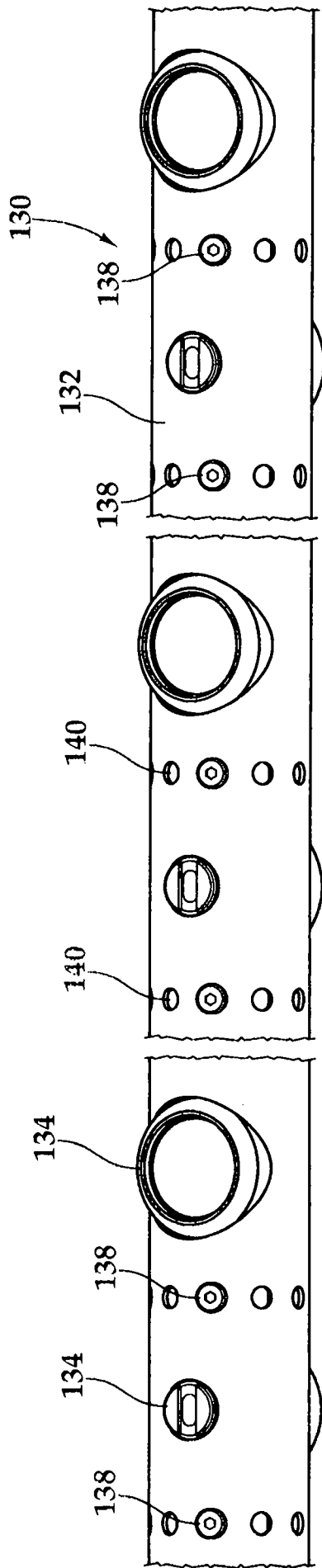


Fig.3A

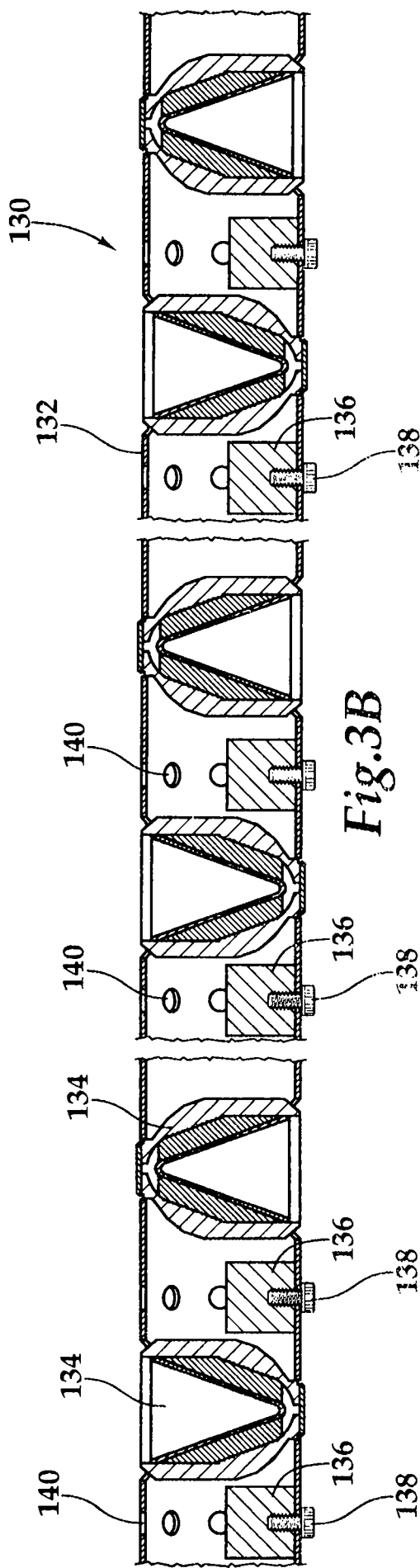


Fig.3B

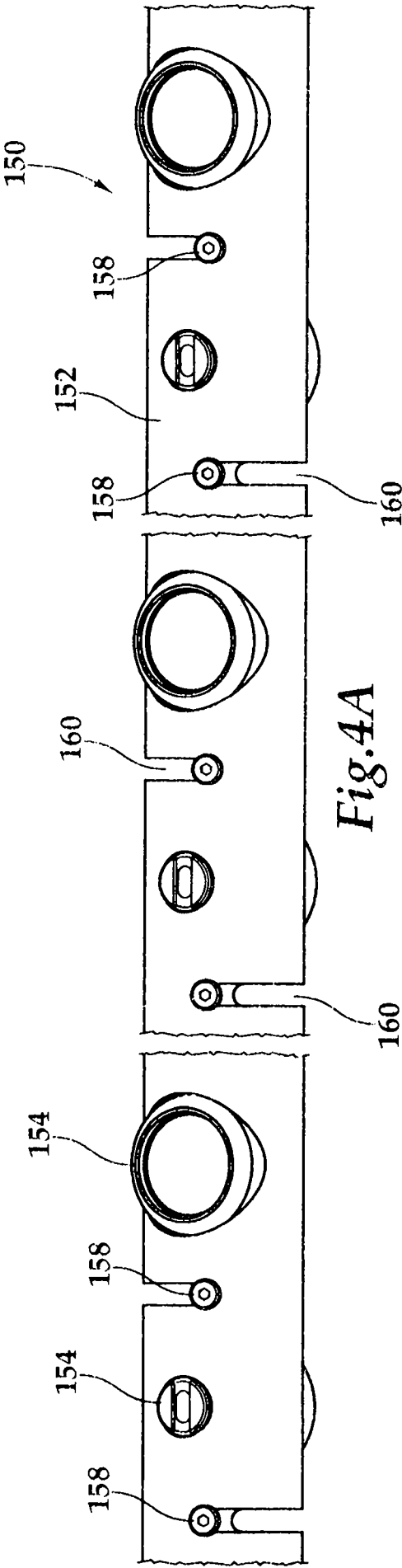


Fig. 4A

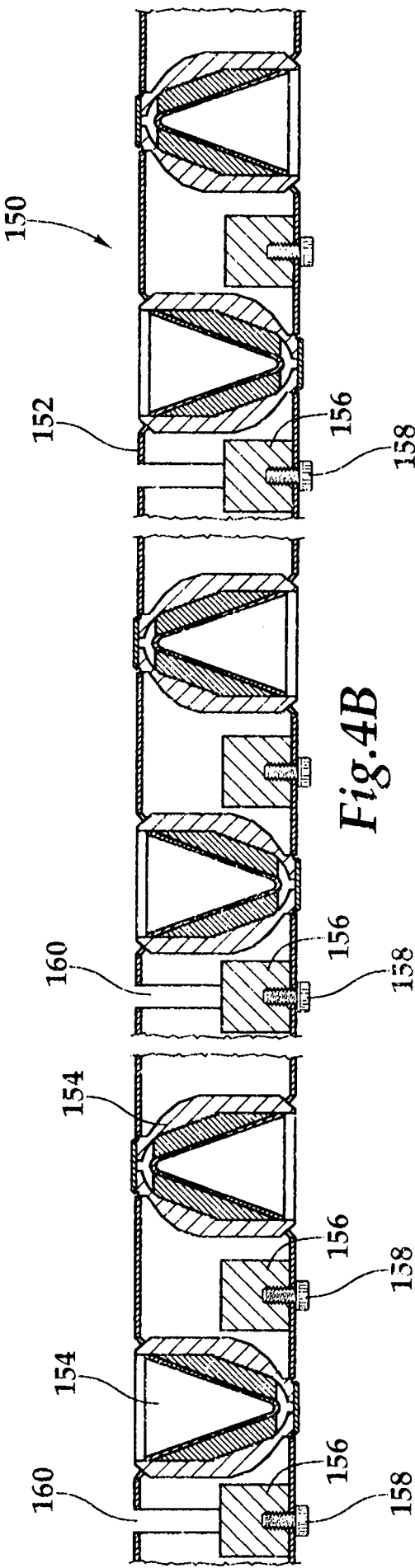
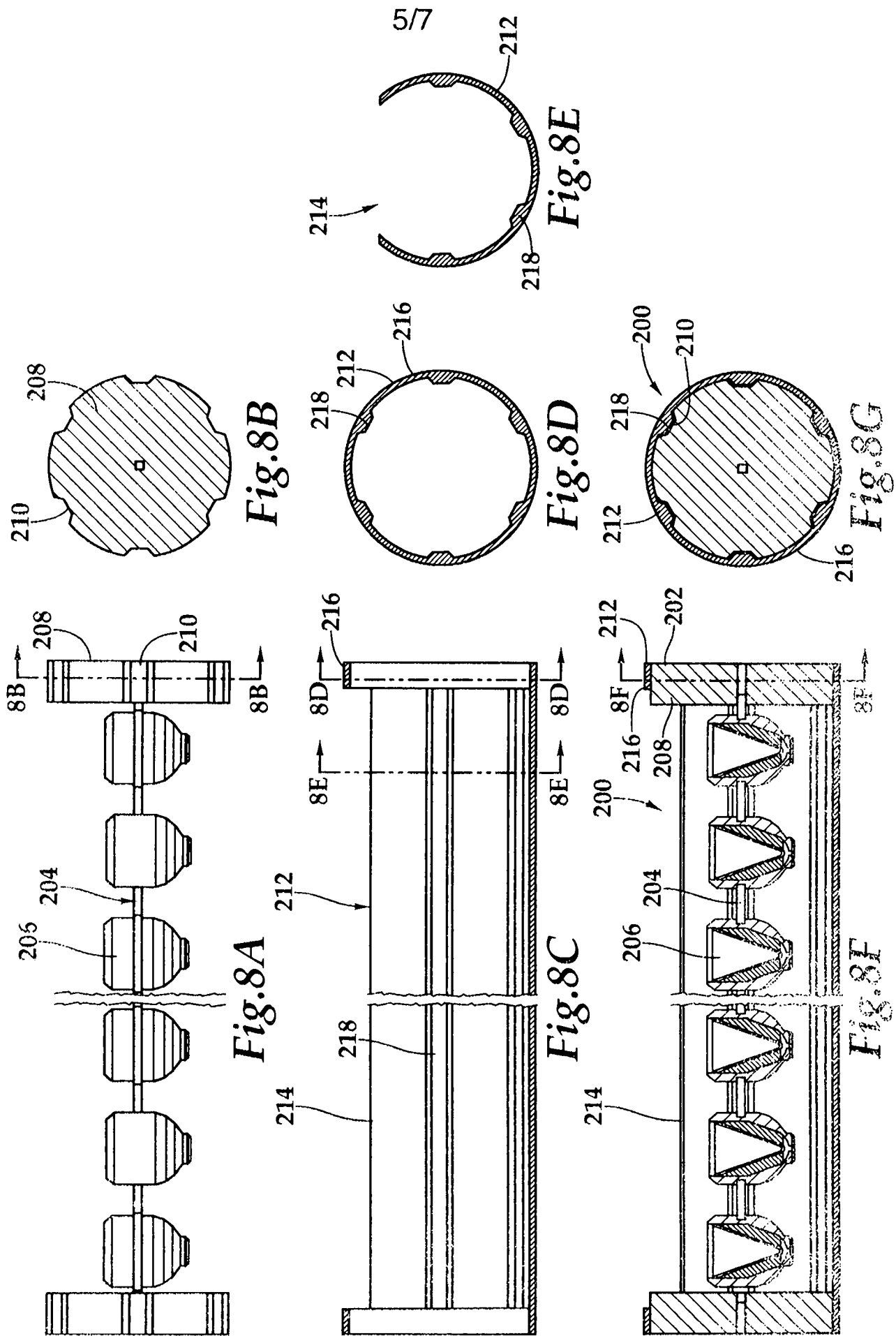
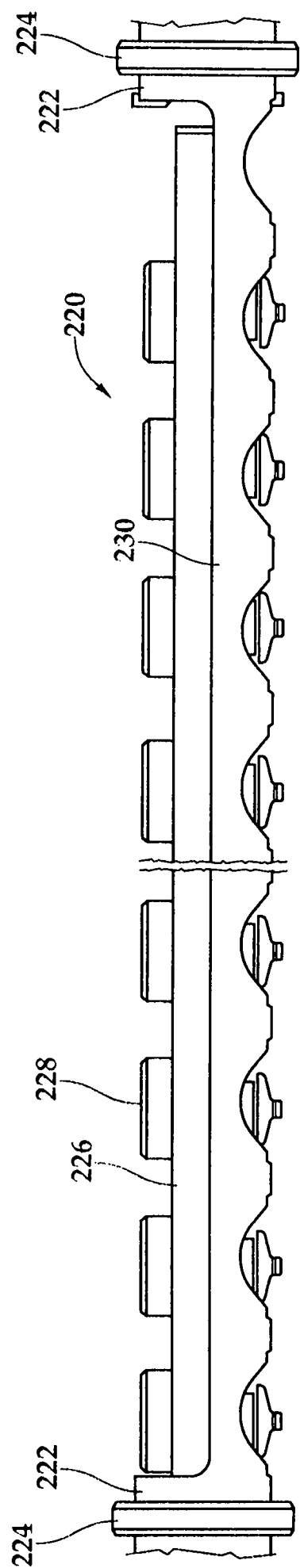
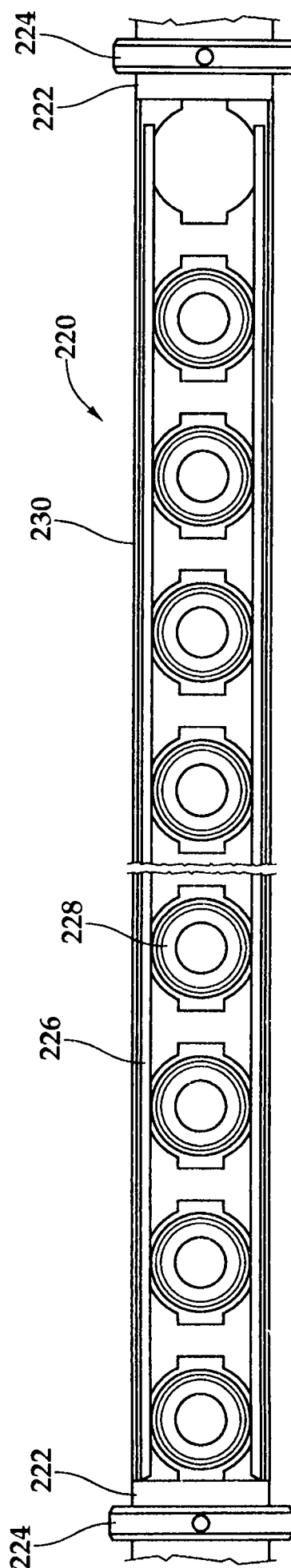


Fig. 4B





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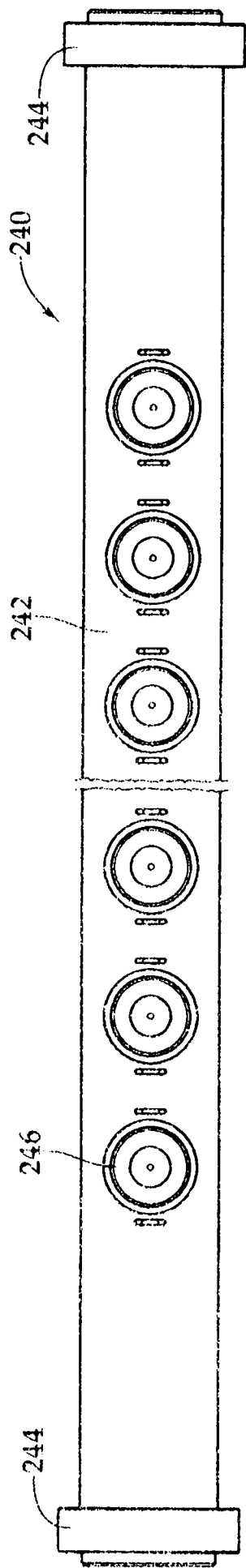


Fig. 10A

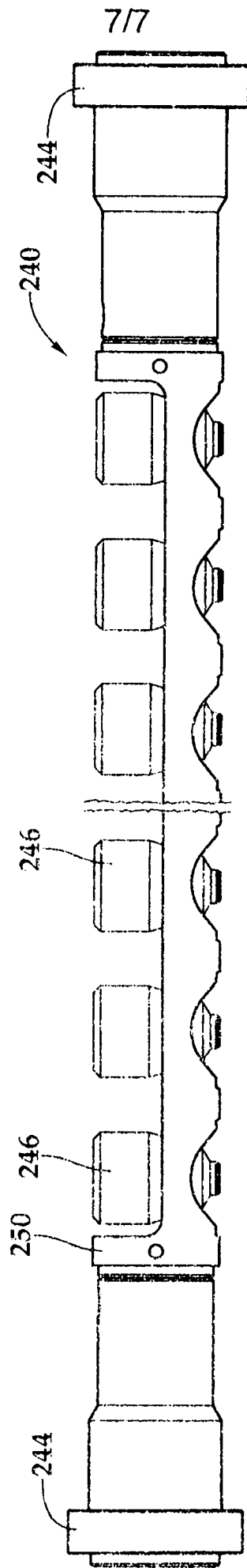


Fig. 10B

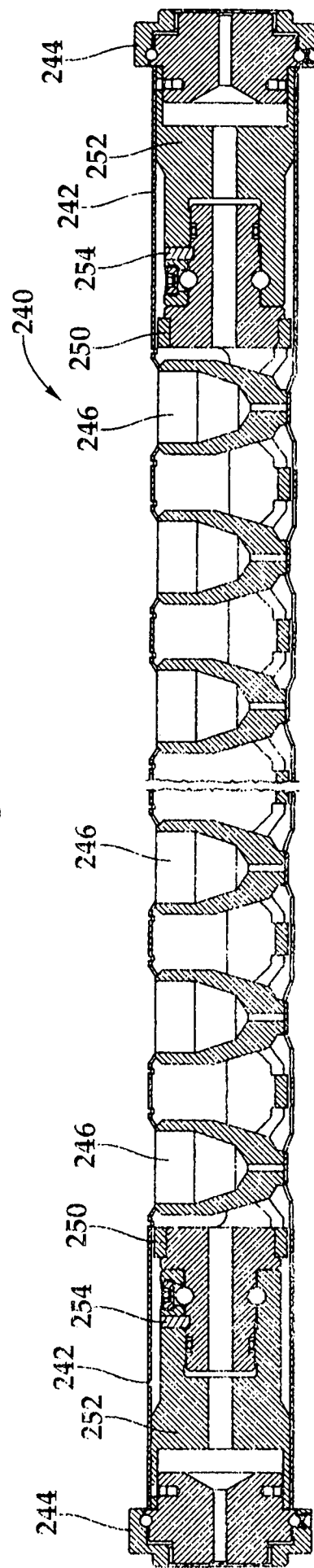


Fig. 10C

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

To:

Youst, Lawrence R.
LAWRENCE YOUST PLLC
2900 McKinnon, Suite 2208
Dallas, TX 75201
ETATS-UNIS D'AMERIQUE

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT AND
THE WRITTEN OPINION OF THE INTERNATIONAL
SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 09-019314 U1	Date of mailing (day/month/year) 27 September 2010 (27-09-2010)
International application No. PCT/US2010/023545	International filing date (day/month/year) 9 February 2010 (09-02-2010)
Applicant HALLIBURTON ENERGY SERVICES, INC.	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338 82.70

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

- ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.
- ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. Reminders

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, National Chapters.

Name and mailing address of the International Searching Authority  European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040 Fax: (+31-70) 340-3016	Authorized officer KERMANI, Nathalie Tel. +49 (0)89 2399-7740
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NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Annex B).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, International Phase, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 23 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet or sheets containing a complete set of claims in replacement of all the claims previously filed must be submitted.

Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively in Arabic numerals (Section 205(a)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

- (i) the claim is unchanged;
- (ii) the claim is cancelled;
- (iii) the claim is new;
- (iv) the claim replaces one or more claims as filed;
- (v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/IPEA/401).

If a demand for international preliminary examination is made, the written opinion of the International Searching Authority will, except in certain cases where the International Preliminary Examining Authority did not act as International Searching Authority and where it has notified the International Bureau under Rule 66.1 bis(b), be considered to be a written opinion of the International Preliminary Examining Authority. If a demand is made, the applicant may submit to the International Preliminary Examining Authority a reply to the written opinion together, where appropriate, with amendments before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later (Rule 43 bis.1(c)).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see the *PCT Applicant's Guide*, National Chapters.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 09-019314 U1	FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, Item 5 below.	
International application No. PCT/US2010/023545	International filing date (day/month/year) 09/02/2010	(Earliest) Priority Date (day/month/year) 13/03/2009
Applicant HALLIBURTON ENERGY SERVICES, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the **language**, the international search was carried out on the basis of:

- ☒ the international application in the language in which it was filed
☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6bis(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (See Box No. II)

3. ☐ **Unity of invention is lacking** (see Box No. III)

4. With regard to the **title**,

- ☒ the text is approved as submitted by the applicant
☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

- ☒ the text is approved as submitted by the applicant
☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings**,

- a. the figure of the **drawings** to be published with the abstract is Figure No. 2
☒ as suggested by the applicant
☐ as selected by this Authority, because the applicant failed to suggest a figure
☐ as selected by this Authority, because this figure better characterizes the invention
 b. ☐ none of the figures is to be published with the abstract

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2010/023545

A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B43/119

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/098158 A1 (GEORGE FLINT R [US] ET AL) 29 May 2003 (2003-05-29) paragraph [0033] figure 2	1-6, 8-21, 23-26
X	US 2003/188867 A1 (PARROTT ROBERT A [US] ET AL PARROTT ROBERT A [RU] ET AL) 9 October 2003 (2003-10-09) claim 1	1,18
A	US 4 637 478 A (GEORGE FLINT R [US]) 20 January 1987 (1987-01-20) column 6, line 64 - column 7, line 8 figure 12	1-26



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

20 September 2010

Date of mailing of the international search report

27/09/2010

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Schouten, Adri

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2010/023545

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003098158 A1	29-05-2003	GB 2388893 A NO 20025662 A	26-11-2003 30-05-2003
US 2003188867 A1	09-10-2003	GB 2401383 A NO 20041888 A RU 2280150 C2 US 2008264639 A1	10-11-2004 10-11-2004 20-07-2006 30-10-2008
US 4637478 A	20-01-1987	CA 1211040 A1 GB 2128719 A	09-09-1986 02-05-1984

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

PCT

To:

see form PCT/ISA/220

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY
(PCT Rule 43bis.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.
PCT/US2010/023545

International filing date (day/month/year)
09.02.2010

Priority date (day/month/year)
13.03.2009

International Patent Classification (IPC) or both national classification and IPC
INV. E21B43/119

Applicant
HALLIBURTON ENERGY SERVICES, INC.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA:



European Patent Office
D-80298 Munich
Tel. +49 89 2399 - 0
Fax: +49 89 2399 - 4465

Date of completion of
this opinion

see form
PCT/ISA/210

Authorized Officer

Schouten, Adri

Telephone No. +49 89 2399-6018



WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2010/023545

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:
 - ☒ the international application in the language in which it was filed
 - ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).
2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished:
 - a. (means)
 - ☐ on paper
 - ☐ in electronic form
 - b. (time)
 - ☐ in the international application as filed
 - ☐ together with the international application in electronic form
 - ☐ subsequently to this Authority for the purposes of search
4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	<u>3, 4, 7, 8, 12-17, 20-23</u>
	No: Claims	<u>1, 2, 5, 6, 9-11, 18, 19, 24-26</u>
Inventive step (IS)	Yes: Claims	<u>7, 22</u>
	No: Claims	<u>1-6, 8-21, 23-26</u>
Industrial applicability (IA)	Yes: Claims	<u>1-26</u>
	No: Claims	

2. Citations and explanations

see separate sheet

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/US2010/023545

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following document:

D1 US 2003/098158 A1 (GEORGE FLINT R [US] ET AL) 29 May 2003 (2003-05-29)

2 INDEPENDENT CLAIM 1

2.1 The present application does not meet the criteria of Article 33(2) PCT, because the subject-matter of independent apparatus claim 1 is not new.

D1 discloses in paragraph [0033] and in figure 2 (the references in parentheses applying to this document):

A perforating apparatus (30) used to perforate a subterranean well, the perforating apparatus (30) comprising:

- a generally tubular gun carrier (36);
- a charge holder (34) rotatably mounted within the gun carrier (36);
- at least one shaped charge (32) mounted in the charge holder (34) and operable to perforate the well upon detonation; and
- a dynamically adjustable weight system (54) operably associated with the charge holder (34), the dynamically adjustable weight system (54) operable to adjust the center of gravity of the charge holder (34) such that gravity will cause the charge holder (34) to rotate within the gun carrier (36) to position the at least one shaped charge (32) in a desired circumferential direction relative to the well prior to perforating.

3 INDEPENDENT CLAIM 18

3.1 The present application does not meet the criteria of Article 33(2) PCT, because the subject-matter of independent method claim 18 is not new.

D1 discloses in paragraph [0033] and in figure 2 (the references in parentheses applying to this document):

A method of perforating a subterranean well comprising the steps of:

- identifying at least one undesired circumferential direction associated with a perforating interval in the well;
- adjusting components of a dynamically adjustable weight system (54) to change the center of gravity of a charge holder (34) rotatably mounted within a gun carrier (36);

- positioning the gun carrier (36) within the perforating interval in the well;
- gravitationally aligning at least one shaped charge (32) mounted in the charge holder (34) in at least one desired circumferential direction relative to the well that does not correspond with the at least one undesired circumferential direction; and
- firing the at least one shaped charge (32) to perforate the well in the at least one desired circumferential direction.

4 INDEPENDENT CLAIM 12

- 4.1 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of claim 12 does not involve an inventive step in the sense of Article 33(3) PCT.

5 DEPENDENT CLAIMS 2-6,8-11,13-17,19-21,23-26

- 5.1 Dependent claims 2-6,8-11,13-17,19-21,23-26 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, for the following reasons:
- claims 2,5,6,9-11,19,24-26 (novelty): see D1, paragraph [0033] and figure 2;
 - claims 3,4,8,13-17,20,21,23 (inventive step): with D1 as the closest prior art, the features of claims 3,4,8,13-17,20,21,23 are merely one of several straightforward possibilities from which the skilled person would select, in accordance with circumstances, without the exercise of inventive skill, in order to solve the problem posed.

6 DEPENDENT CLAIMS 7,22

- 6.1 The combination of the features of dependent claims 7 or 22 is neither known from, nor rendered obvious by, the available prior art.

Re Item VII

Certain defects in the international application

- Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in D1 is not mentioned in the description, nor is this document identified therein.
- Independent claims 1,12,18 are not in the two-part form in accordance with Rule 6.3 (b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art D1 being placed in the preamble (Rule 6.3(b)(i) PCT) and the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).
- The features of claims 1-26 are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).
- The unit foot employed in paragraph [0043] is not recognised in international practice, contrary to the requirements of Rule 10.1(d) PCT.

Re Item VIII

Certain observations on the international application

The application does not meet the requirements of Article 6 PCT, because claims 1-26 are not concise.

Although claims 1 and 12 have been drafted as separate independent apparatus claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought and/or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness and as such do not meet the requirements of Article 6 PCT.

Possible steps after receipt of the international search report (ISR) and written opinion of the International Searching Authority (WO-ISA)

General information	For all international applications filed on or after 01/01/2004 the competent ISA will establish an ISR. It is accompanied by the WO-ISA. Unlike the former written opinion of the IPEA (Rule 66.2 PCT), the WO-ISA is not meant to be responded to, but to be taken into consideration for further procedural steps. This document explains about the possibilities.
Amending claims under Art. 19 PCT	Within 2 months after the date of mailing of the ISR and the WO-ISA the applicant may file amended claims under Art. 19 PCT directly with the International Bureau of WIPO. The PCT reform of 2004 did not change this procedure. For further information please see Rule 46 PCT as well as form PCT/ISA/220 and the corresponding Notes to form PCT/ISA/220.
Filing a demand for international preliminary examination	In principle, the WO-ISA will be considered as the written opinion of the IPEA. This should, in many cases, make it unnecessary to file a demand for international preliminary examination. If the applicant nevertheless wishes to file a demand this must be done before expiry of 3 months after the date of mailing of the ISR/ WO-ISA or 22 months after priority date, whichever expires later (Rule 54bis PCT). Amendments under Art. 34 PCT can be filed with the IPEA as before, normally at the same time as filing the demand (Rule 66.1 (b) PCT). If a demand for international preliminary examination is filed and no comments/amendments have been received the WO-ISA will be transformed by the IPEA into an IPRP (International Preliminary Report on Patentability) which would merely reflect the content of the WO-ISA. The demand can still be withdrawn (Art. 37 PCT).
Filing informal comments	After receipt of the ISR/WO-ISA the applicant may file informal comments on the WO-ISA directly with the International Bureau of WIPO. These will be communicated to the designated Offices together with the IPRP (International Preliminary Report on Patentability) at 30 months from the priority date. Please also refer to the next box.
End of the international phase	At the end of the international phase the International Bureau of WIPO will transform the WO-ISA or, if a demand was filed, the written opinion of the IPEA into the IPRP, which will then be transmitted together with possible informal comments to the designated Offices. The IPRP replaces the former IPER (international preliminary examination report).
Relevant PCT Rules and more information	Rule 43 PCT, Rule 43bis PCT, Rule 44 PCT, Rule 44bis PCT, PCT Newsletter 12/2003, OJ 11/2003, OJ 12/2003

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 September 2010 (16.09.2010)



(10) International Publication Number
WO 2010/104634 A2

(51) International Patent Classification:

E21B 43/119 (2006.01) E21B 43/117 (2006.01)
E21B 43/116 (2006.01)

(21) International Application Number:

PCT/US2010/023545

(22) International Filing Date:

9 February 2010 (09.02.2010)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

12/403,420 13 March 2009 (13.03.2009) US

(71) Applicant (for all designated States except US): **HAL-LIBURTON ENERGY SERVICES, INC.** [US/US];
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(72) Inventors; and

(75) Inventors/Applicants (for US only): **HALES, John H.** [US/US]; 2601 Beltline Road, Carrollton, TX 75006 (US). **NOVAK, Allison E.** [US/US]; 2601 Beltline Road, Carrollton, TX 75006 (US). **BURLESON, John D.** [US/US]; 2601 Beltline Road, Carrollton, TX 75006 (US).

(74) Agent: **YOUST, Lawrence R.**; LAWRENCE YOUST PLLC, 2900 McKinnon, Suite 2208, Dallas, TX 75201 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

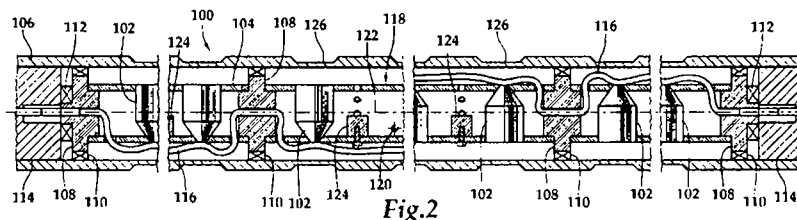
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(54) Title: SYSTEM AND METHOD FOR DYNAMICALLY ADJUSTING THE CENTER OF GRAVITY OF A PERFORATING APPARATUS



(57) Abstract: A perforating apparatus (100) used to perforate a subterranean well. The perforating apparatus (100) includes a generally tubular gun carrier (106) and a charge holder (104) rotatably mounted within the gun carrier (106). At least one shaped charge (102) is mounted in the charge holder (104) and is operable to perforate the well upon detonation. A dynamically adjustable weight system (124) is operably associated to the charge holder (104). The dynamically adjustable weight system (124) is operable to adjust the center of gravity (120) of the charge holder (104) such that gravity will cause the charge holder (104) to rotate within the gun carrier (106) to position the at least one shaped charge (102) in a desired circumferential direction relative to the well prior to perforating.

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SYSTEM AND METHOD FOR DYNAMICALLY ADJUSTING THE CENTER OF GRAVITY OF A PERFORATING APPARATUS

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TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates, in general, to perforating a wellbore that traverses a fluid bearing subterranean formation using shaped charges and, in particular, to an apparatus and
10 method for dynamically adjusting the center of gravity of a perforating apparatus.

BACKGROUND OF THE INVENTION

[0002] Without limiting the scope of the present invention, its background will be described with reference to perforating a subterranean formation with a shaped charge perforating
15 apparatus, as an example.

[0003] After drilling the various sections of a subterranean wellbore that traverses a formation, individual lengths of relatively large diameter metal tubulars are typically secured together to form a casing string that is positioned within the wellbore. This casing string increases the integrity of the wellbore and provides a path for producing fluids from the
20 producing intervals to the surface. Conventionally, the casing string is cemented within the wellbore. To produce fluids into the casing string, hydraulic opening or perforation must be made through the casing string, the cement and a short distance into the formation.

[0004] Typically, these perforations are created by detonating a series of shaped charges located within the casing string that are positioned adjacent to the desired formation.
25 Specifically, one or more charge carriers are loaded with shaped charges that are connected with a detonating device, such as detonating cord. The charge carriers are then connected within a tool string that is lowered into the cased wellbore at the end of a tubing string, wireline, slick line, coil tubing or the like. Once the charge carriers are properly positioned in the wellbore such that the shaped charges are adjacent to the formation to be perforated, the
30 shaped charges are detonated. Upon detonation, the shaped charges create jets that blast through scallops or recesses in the carrier. Each jet creates a hydraulic opening through the casing and the cement and enters the formation forming a perforation.

[0005] It has been found, however, that it is sometimes desirable to perforate a wellbore in a particular direction or range of directions relative to the wellbore. For example, in a deviated,
35 inclined or horizontal well, it is frequently beneficial to form perforations in the upward

direction, the downward direction or both. Attempts have been made to achieve this goal of perforating wells in particular directions. One method of orienting perforating charges downhole requires the charges to be rigidly mounted in a gun carrier so that they are pointed in the desired directions relative to the carrier. The gun carrier is then conveyed into a wellbore and either laterally biased physically to one side of the wellbore so that the gun carrier seeks the lower portion of the wellbore due to gravity, or the gun carrier is rotatably supported with its center of gravity laterally offset relative to the wellbore. This method relies on the gun carrier rotating in the wellbore, so that the gun carrier may be oriented relative to the force of gravity. Frequently, such orienting rotation is unreliable due to friction between the gun carrier and the wellbore, debris in the wellbore or the like.

[0006] More recently, the assignee of the present invention has developed a perforating gun that includes a tubular gun carrier, multiple perforating charges, multiple charge mounting structures and multiple rotating supports. This internally oriented perforating apparatus has successfully provided increased reliability in orienting perforating charges to shoot in the desired directions in a well. In this design, the direction or directions of the perforations is established when the gun is assembly in its manufacturing facility.

[0007] It has been found, however, that in certain installations, it is necessary to avoid shooting in a particular direction or directions. For example, one or more communication conduits or controls lines may extend along the exterior of the casing string. During installation, these conduits commonly become wound around the casing string such that the exact location of these lines can only determined after installation by, for example, logging the well.

[0008] A need has therefore arisen for an apparatus and method operable to achieve reliable downhole orientation of the shaped charges in a perforating apparatus such that the shaped charges shoot in desired directions. In addition, a need has arisen for such an apparatus and method operable to achieve reliable downhole orientation of the shaped charges in a perforating apparatus such that the shaped charges do not shoot in undesired directions.

SUMMARY OF THE INVENTION

[0009] The present invention disclosed herein comprises an apparatus and method for dynamically adjusting the center of gravity of a perforating apparatus. The apparatus and method of the present invention are operable to achieve reliable downhole orientation of shaped charges in a perforating apparatus such that the shaped charges shoot in desired directions. In addition, apparatus and method of the present invention are operable to achieve

reliable downhole orientation of shaped charges in a perforating apparatus such that the shaped charges do not shoot in undesired directions

[0010] In one aspect, the present invention is directed to a perforating apparatus used to perforate a subterranean well. The perforating apparatus includes a generally tubular gun carrier having a charge holder rotatably mounted therein. At least one shaped charge is mounted in the charge holder and is operable to perforate the well upon detonation. A dynamically adjustable weight system is operably associated to the charge holder. The dynamically adjustable weight system is operable to adjust the center of gravity of the charge holder such that gravity will cause the charge holder to rotate within the gun carrier to position the at least one shaped charge in a desired circumferential direction relative to the well prior to perforating.

[0011] In one embodiment, the dynamically adjustable weight system includes a plurality of discrete weights that are individually coupled to the charge holder at a plurality of longitudinal locations. In this embodiment, for each of the longitudinal locations, the charge holder may include a plurality of circumferentially distributed openings such as uniformly distributed openings at between about 15 and 60 degree increments. Alternatively, for each of the longitudinal locations, the charge holder may include a circumferentially extending slot that may extend circumferentially between about 90 and 180 degrees.

[0012] In another embodiment, the dynamically adjustable weight system includes a plurality of longitudinally extending tubes operable to contain a weighted material therein. In a further embodiment, the dynamically adjustable weight system includes weights formed from a malleable material. In yet another embodiment, the dynamically adjustable weight system includes a weight tube that is rotatable relative to the charge holder. In any of these embodiments, the at least one shaped charge may include a plurality of shaped charges that may be positioned in the charge holder to fire in substantially the same circumferential direction or the shaped charges may be positioned in the charge holder to fire in multiple circumferential directions.

[0013] In another aspect, the present invention is directed to a perforating apparatus used to perforate a subterranean well. The perforating apparatus includes a generally tubular gun carrier having a charge tube rotatably mounted therein. The charge tube includes a plurality of circumferentially extending slots. At least one shaped charge is mounted in the charge tube and is operable to perforate the well upon detonation. A dynamically adjustable weight system is coupled to the charge tube. The dynamically adjustable weight system includes a plurality of discrete weights that are coupled to the charge tube at the slots such that the

circumferential location of the weights is adjustable along the length of the slots to adjust the center of gravity of the charge tube such that gravity will cause the charge tube to rotate within the gun carrier to position the at least one shaped charge in a desired circumferential direction relative to the well prior to perforating.

5 [0014] In one embodiment, adjacent slots in the charge tube extend in circumferentially opposite directions. In another embodiment, the weights are attached to the charge tube using bolts that are selectively slidable within the slots.

[0015] In another aspect, the present invention is directed to a method of perforating a subterranean well. The method includes identifying at least one undesired circumferential
10 direction associated with a perforating interval in the well; adjusting components of a dynamically adjustable weight system to change the center of gravity of a charge holder rotatably mounted within a gun carrier; positioning the gun carrier within the perforating interval in the well; gravitationally aligning a least one shaped charge mounted in the charge holder in at least one desired circumferential direction relative to the well that does not
15 correspond with the at least one undesired circumferential direction; and firing the at least one shaped charge to perforate the well in the at least one desired circumferential direction.

[0016] The method may also include relocating discrete weights circumferentially about the charge holder. This may be accomplished by relocating the discrete weights relative to circumferentially distributed openings in the charge holder or relocating the discrete weights
20 relative to circumferentially extending slots in the charge holder. Alternatively, the method may include changing the amount of weighted material in at least one longitudinally extending tube, reshaping malleable material disposed within the charge holder or rotating a weight tube relative to the charge holder.

25 BRIEF DESCRIPTION OF THE DRAWINGS

[0017] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

30 [0018] Figure 1 is a schematic illustration of an offshore oil and gas platform operating a plurality of apparatuses for dynamically adjusting the center of gravity of perforating apparatuses of the present invention;

[0019] Figure 2 is a cross sectional view of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0020] Figures 3A-3B are side and cross sectional views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0021] Figures 4A-4B are side and cross sectional views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0022] Figure 5 is a cross sectional view of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0023] Figure 6 is a cross sectional view of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0024] Figures 7A-7B are a cross sectional views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0025] Figures 8A-8G are various views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention;

[0026] Figures 9A-9B are a side and top views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention; and

[0027] Figures 10A-10C are various views of one embodiment of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0028] While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention, and do not delimit the scope of the present invention.

[0029] Referring initially to Figure 1, a plurality of apparatuses for dynamically adjusting the center of gravity of perforating apparatuses operating from an offshore oil and gas platform are schematically illustrated and generally designated 10. A semi-submersible platform 12 is centered over a submerged oil and gas formation 14 located below sea floor 16. A subsea conduit 18 extends from deck 20 of platform 12 to wellhead installation 22 including subsea

blow-out preventers 24. Platform 12 has a hoisting apparatus 26 and a derrick 28 for raising and lowering pipe strings such as work string 30.

[0030] A wellbore 32 extends through the various earth strata including formation 14. A casing 34 is cemented within wellbore 32 by cement 36. Work string 30 includes various tools such as a plurality of perforating apparatuses or guns 38. When it is desired to perforate casing 34, work string 30 is lowered through casing 34 until the perforating guns 38 are properly positioned relative to formation 14. Thereafter, the shaped charges within the string of perforating guns 38 are sequentially fired, either in an uphole to downhole or a downhole to uphole direction. Upon detonation, the liners of the shaped charges form jets that create a spaced series of perforations extending outwardly through casing 34, cement 36 and into formation 14, thereby allow fluid communication between formation 14 and wellbore 32.

[0031] In the illustrated embodiment, wellbore 32 has an initial, generally vertical portion 40 and a lower, generally deviated portion 42 which is illustrated as being horizontal. It should be noted, however, by those skilled in the art that the apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention is equally well-suited for use in other well configurations including, but not limited to, inclined wells, wells with restrictions, non-deviated wells, multilateral wells and the like. In addition, even though an offshore operation has been depicted in figure 1, the apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention is equally well-suited for use in onshore operations.

[0032] Work string 30 includes a packer 44 that may be sealingly engaged with casing 34 and is illustrated in the vertical portion 40 of wellbore 32. At the lower end of work string 30 is the gun string including the plurality of perforating guns 38, a ported nipple 46 and a fire head 48. In the illustrated embodiment, perforating guns 38 include internal orientation features which allow for reliable rotation of the charge tube within the gun carrier as described in United States Patent No. 6,595,290 issued to Halliburton Energy Services, Inc. on July 22, 2003, which is hereby incorporated by reference for all purposes.

[0033] Referring now to figure 2, therein is depicted a perforating apparatus that includes an apparatus for dynamically adjusting the center of gravity of the perforating apparatus of the present invention that is generally designated 100. In the following description of apparatus 100 as well as the other apparatuses and methods described herein, directional terms such as "above", "below", "upper", "lower" and the like are used for convenience in referring to the illustrations as it is to be understood that the various embodiments of the invention may be

used in various orientations such as inclined, inverted, horizontal, vertical and the like and in various configurations, without departing from the principles of the invention.

[0034] Gun 100 includes a plurality of shaped charges 102 that are securably mounted in a charge holder that is depicted as charge tube 104. Charge tube 104 is rotatably mounted within gun carrier 106. Preferably, charge tube 104 is made from cylindrical tubing, but it should be understood that it is not necessary for charge tube 104 to be tubular or have a cylindrical shape in keeping with the principles of the invention. Charge tube 104 includes multiple supports 108 that allow charge tube 104 to rotate within gun carrier 106. This manner of rotatably supporting charge tube 104 prevents charges 102 or any other portion of charge tube 104 from contacting the interior of gun carrier 106.

[0035] Each of the supports 108 includes rolling elements or bearings 110 contacting the interior of gun carrier 106. For example, bearings 110 could be ball bearings, roller bearings, plain bearings or the like. Bearings 110 enable supports 108 to suspend charge tube 104 in gun carrier 106 and permit rotation thereof. In addition, optional thrust bearings 112 may be positioned between each end of charge tube 104 and gun carrier 106 such that thrust bearings 112 contact devices 114 attached at each end of gun carrier 106. Each device 114 may be tandems that are used to couple two guns to each other, a bull plug used to terminate a gun string, a firing head, or any other type of device which may be attached to gun carrier 106. As with bearings 110 described above, thrust bearings 112 may be any type of bearings. Thrust bearings 112 support charge tube 104 against axial loading within gun carrier 106, while permitting charge tube 104 to rotate within gun carrier 106.

[0036] Charge tube 104, charges 102 and other portions of gun 100 supported in gun carrier 106 by the supports 108 including, for example, a detonating cord 116 extending to each of the charges and portions of the supports themselves, are parts of an overall rotating assembly 118. By offsetting a center of gravity 120 of assembly 118 relative to a longitudinal rotational axis 122 of bearings 110, assembly 118 is biased by gravity to rotate to a specific position in which the center of gravity 120 is located directly below the rotational axis 122.

[0037] Assembly 118 may, due the construction of the various elements thereof, initially have the center of gravity 120 in a desired position relative to charges 102. However, to ensure that charges 102 are directed to shoot in respective predetermined directions, the center of gravity 120 may be repositioned using a dynamically adjustable weight system that is depicted as weights 124. In the illustrated embodiment, on the left side of figure 2, weights 124 are added to assembly 118 to direct the charges 102 to shoot upward, while on the right side of figure 2, weights 124 are added to assembly 118 to direct the charges 102 to shoot

downward. As discussed in greater detail below, weights 124 may be otherwise positioned to direct the charges 102 to shoot in any desired direction, or combination of directions and to avoid shooting in undesired directions.

[0038] Gun carrier 106 is provided with reduced wall thickness portions 126, which extend circumferentially about carrier 106 outwardly overlying each of the charges 102. Thus, as the charges 102 rotate within carrier 106, they remain directed to shoot through the portions 126. The reduced wall thickness portions 126 may be formed on carrier 106 by rolling, forging, lathe cutting or any other suitable technique.

[0039] Referring next to figures 3A and 3B, therein are depicted side and cross sectional views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 130. Apparatus 130 includes a charge holder depicted as charge tube 132 which houses a plurality of shaped charges 134. In the illustrated embodiment, shaped charges 134 are configured in a 180 degree phased pattern, however, those skilled in the art will appreciate that any number of alternative phased patterns of the shaped charges are possible and are considered within the scope of the present invention.

[0040] Apparatus 130 also includes a dynamically adjustable weight system depicted as weights 136. In the illustrated embodiment, each of the weights 136 includes a threaded portion that is operable to receive therein a complementary threaded bolt 138. Weights 136 are accordingly attached to charge tube 132 by passing the shaft portion of a bolt 138 through one of a plurality of openings 140 in charge tube 132 and then rotatably coupling that bolt 138 to one of the weights 136. As illustrated, each longitudinal location of charge tube 132 that is designed to receive a weight 136 has eight openings 140 that are circumferentially spaced apart at 45 degree increments. It should be understood by those skilled in the art, however, that any number of openings having any desired circumferentially spacing both uniform and nonuniform is possible and is considered within the scope of the present invention, so long as the structural integrity of charge tube 132 is maintained. For example, it may be desirable to have openings that are circumferentially spaced uniformly around a charge tube at between about 15 and about 60 degree increments.

[0041] As used herein, the term dynamically adjustable refers to the ability to change the center of gravity of a perforating apparatus in the field as opposed to only as the perforating apparatus is manufactured. This ability provides the versatility to make adjustments to apparatus 130 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line

disposed to the exterior of the casing string. Continuing with this example, if one or more control lines are position to the exterior of the casing string, it is imperative to avoid causing damage to the control lines during the perforating process. As these control lines commonly take on a spiral configuration around the casing string during installation, the actual location of the control lines must be determined prior to perforating the well by, for example, logging the well. Once the circumferential location of the control lines is known for each depth of the well, the present invention allows field personnel to custom design the perforating gun string such that the control lines can be avoided and the well can be perforated in the desired directional orientations.

[0042] In the illustrated embodiment, this is accomplished by repositioning the weights 136 relative to any one of the respective openings 140 circumferentially spaced around charge tube 132. For example, if charge tube 132 were installed within a gun carrier as configured in figure 3B and deployed in a horizontal well, weights 136 would cause charge tube 132 to rotate to the position depicted in figure 3B wherein shaped charges 134 would fire at 0 and 180 degrees in the well. If weights 136 were each moved to the next adjacent position, shaped charges 134 would fire at 45 and 225 degrees in the well. Likewise, if weights 136 were each moved again to the next adjacent position, shaped charges 134 would fire at 90 and 270 degrees in the well. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0043] Even though figures 3A-3B have depicted apparatus 130 as having one weight positioned between adjacent shaped charge, it should be understood by those skilled in the art that no particular relationship is required between the number of weights and the number of shaped charges in a given perforating apparatus. The number and configuration of the weights and shaped charges will vary based upon factors such as the desired shots per foot, the diameter of the charge tube, the explosive mass of the charges, the size of the weights, the spacing between charges and the like. The important factor is that the center of gravity is dynamically adjustable to cause the charge tube to rotate within the gun carrier to the desired position.

[0044] Referring next to figures 4A and 4B, therein are depicted side and cross sectional views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 150. Apparatus 150 includes a charge holder depicted as charge tube 152 which houses a plurality of shaped charges 154. In the illustrated embodiment, shaped charges 154 are configured in a 180 degree phased

pattern, however, those skilled in the art will appreciate that any number of alternative phased patterns of the shaped charges are possible and are considered within the scope of the present invention.

[0045] Apparatus 150 also includes a dynamically adjustable weight system depicted as weights 156. In the illustrated embodiment, each of the weights 156 includes a threaded portion that is operable to receive therein a complementary threaded bolt 158. Weights 156 are accordingly attached to charge tube 152 by passing the shaft portion of a bolt 158 through a slot 160 in charge tube 152 and then rotatably coupling that bolt 158 to one of the weights 156. As illustrated, each longitudinal location of charge tube 152 that is designed to receive a weight 156 has a slot 160 that circumferentially traverses 180 degrees of charge tube 152. Adjacent slots 160 of apparatus 150 are configured such that they extend on opposite sides of charge tube 152. This design enhances the structural integrity of charge tube 152 and allows for infinite variability in the center of gravity of apparatus 150. In certain implementations, weights 156 may be placed in each of the slots 160. In other implementations, it may be desirable to have weights 156 in every other slot 160 such that each of the weights 156 can be positioned at the same circumferential position. It should be understood by those skilled in the art that slots 160 could have other circumferential orientations and could have other relative spacing arrangement, both uniform and nonuniform, without departing from the principles of the present invention, so long as the structural integrity of charge tube 152 is maintained.

[0046] As discussed above, the combination of slots 160 and weights 156 allow for dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 150 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by circumferentially repositioning the weights 156 along slots 160 by loosening bolts 158, sliding the weights 156 to the desired circumferential position and rescuring the weights 156 to charge tube 152 with the bolts 158. If charge tube 152 were installed within a gun carrier as loaded in figure 4B and deployed in a horizontal well, weights 156 would cause charge tube 152 to rotate to the position depicted in figure 4B wherein shaped charges 154 would fire at 0 and 180 degrees in the well. Repositioning of the weights 156 along slots 160, as described above, would allow for firing in any desired circumferential directions. Accordingly, the directions the shaped charges will perforate the

well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0047] Referring next to figure 5, therein is depicted a cross sectional view of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 170. Apparatus 170 includes a charge holder depicted as charge tube 172 which houses a plurality of shaped charges (not pictured). Apparatus 170 also includes a dynamically adjustable weight system 174 that is depicted a plurality of tubes 176. Tubes 176 extend at least partially longitudinally within charge tube 172 and are operable to contain a weighted material such as a fluid or a solid. As illustrated, apparatus 170 includes seven tubular tubes 176 that are circumferentially distributed within charge tube 172 at 30 degree increments. It should be understood by those skilled in the art that tubes 176 could have other circumferential orientations, both uniform and nonuniform, within charge tube 172 without departing from the principles of the present invention. Likewise, even though tubes 176 are depicted as having a tubular cross section, tubes 176 could alternatively have other cross sections including, but not limited to, oval cross sections, rectangular cross sections, arc shaped cross sections and the like. In addition, those skilled in the art will recognize that not all of tubes 176 need to have the same cross section or be of the same size.

[0048] In operation, dynamically adjustable weight system 174 of apparatus 170 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 170 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by adding or reducing the weight within tubes 176 by, for example, adding or removing a fluid such as water from tubes 176. As the weight is adjusted in the various tubes 176, the desired downhole rotation of charge tube 172 can be achieved. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0049] Referring next to figure 6, therein is depicted a cross sectional view of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 180. Apparatus 180 includes a charge holder depicted as charge tube 182 which houses a plurality of shaped charges (not pictured). Apparatus 180 also includes a dynamically adjustable weight system 184 that is depicted a plurality of tubes

186. Tubes 186 extend at least partially longitudinally along the exterior of charge tube 182 and are operable to contain a weighted material such as a fluid or a solid. As illustrated, apparatus 180 includes seven tubular tubes 186 that are circumferentially distributed within charge tube 182 at 30 degree increments. It should be understood by those skilled in the art that tubes 186 could have other circumferential orientations, both uniform and nonuniform, within charge tube 182 without departing from the principles of the present invention. Likewise, even though tubes 186 are depicted as having a tubular cross section, tubes 186 could alternatively have other cross sections including, but not limited to, oval cross sections, rectangular cross sections, arc shaped cross sections and the like. In addition, those skilled in the art will recognize that not all of tubes 186 need to have the same cross section or be of the same size.

[0050] In operation, dynamically adjustable weight system 184 of apparatus 180 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 180 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by adding or reducing the weight within tubes 186 by, for example, adding or removing a fluid such as water from tubes 186. As the weight is adjusted in the various tubes 186, the desired downhole rotation of charge tube 182 can be achieved. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0051] Even though figures 5 and 6 have depicted tubes located respectively inside and outside of a charge tube that are operable to receive a weighted material therein, those skilled in the art should recognize that alternate configurations could also be used and would be considered within the scope of the present invention including, but not limited to, forming one or more passageways in the wall of the charge tube or similar tubular operable to receive a weighted material therein.

[0052] Referring next to figures 7A and 7B, therein is depicted cross sectional views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 190. Apparatus 190 includes a charge holder depicted as charge tube 192 which houses a plurality of shaped charges (not pictured). Apparatus 190 also includes a dynamically adjustable weight system 194 that is depicted as malleable weight members 196 that may be formed from a metal such as lead or a polymer.

Malleable weight members 196 may extend at least partially longitudinally along the interior of charge tube 192 or may be discrete weight elements similar to weights 136 and 156 described above. As illustrated, each malleable weight member 196 is coupled to charge tube 192 using one or more bolts 198. In operation, dynamically adjustable weight system 194 of apparatus 190 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 190 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by applying pressure or force to the malleable material that forms malleable weight members 196 using, for example, an adjustment tool that is sized to extend into charge tube 192. The location of at least a portion of the mass of malleable weight members 196 can then be adjusted, as seen in a comparison of figures 7A and 7B, such that the desired downhole rotation of charge tube 192 can be achieved. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0053] Referring next to figures 8A-8G, therein are depicted various views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 200. When assembled, apparatus 200 forms a rotating assembly 202 that is rotatably mounted in a gun carrier in a manner described above. Apparatus 200 includes a charge holder 204 that supports a plurality of shaped charges 206. Charge holder 204 is coupled to end plates 208. Each end plate 208 includes a plurality of notches 210 that are illustrated as being positioned circumferentially around end plates 208 at 60 degree increments, however, those skilled in the art will recognize that notches 210 could have alternate configurations including having different circumferential spacing. In addition, depending upon the length of charge holder 204, it may be desirable to have additional structures that are similar to end plates 208 positioned at intermediate locations along charge holder 204 between certain shaped charges 206. Apparatus 200 also includes a dynamically adjustable weight system depicted as weight tube 212. Weight tube 212 is formed from a substantially tubular member having a window 214, as best seen in figure 8E. In the illustrated embodiment, window 214 extends about 120 degrees circumferentially around weight tube 212, however, those skilled in the art will recognize that window 214 could have alternate configurations including having a different circumferential width or multiple

window sections circumferential distributed around weight tube 212. Weight tube 212 includes circumferential end sections 216 that are sized to closely receive end plates 208. Weight tube 212 includes a plurality of rails 218 that are designed to mesh with notches 210 of end plates 208.

5 [0054] In operation, the dynamically adjustable weight system of apparatus 200 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 200 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to
10 the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by inserting charge holder 204 into weight tube 212 such that shaped charges 206 are oriented in the desired direction. For example, if charge holder 204 were installed within weight tube 212 as shown in figure 8F and deployed in a horizontal well, weight tube 212 would cause rotating assembly 202 to rotate to the position depicted in
15 figure 8F wherein shaped charges 206 would fire at 0 degrees in the well. If charge holder 204 was rotated 60 degrees in either direction to realign rails 218 and notches 210, shaped charges 206 would fire at either 60 degrees or 300 degrees in the well. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

20 [0055] Referring next to figures 9A-9B, therein are depicted side and top views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 220. When assembled, apparatus 220 forms a rotating assembly 222 that is rotatably mounted in a gun carrier in a manner described above via bearings 224. Apparatus 220 includes a charge holder 226 that supports a plurality of
25 shaped charges 228. Apparatus 220 also includes a dynamically adjustable weight system depicted as weight tube 230. Weight tube 230 is formed from a partially tubular member. Charge holder 226 is selectively rotatable mounted within weight tube 230 such that charge holder 226 may be rotated about 120 degrees circumferentially within weight tube 230. In operation, the dynamically adjustable weight system of apparatus 220 allows field personnel
30 to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 220 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated

embodiment, this is accomplished by selectively releasing a connection such as a pin, a set screw or the like between charge holder 226 and weight tube 230 then rotating charge holder 226 such that shaped charges 228 are oriented in the desired direction. For example, if charge holder 226 was installed within weight tube 230 as shown in figure 9A and deployed in a horizontal well, weight tube 230 would cause rotating assembly 222 to rotate to the position depicted in figure 9A wherein shaped charges 228 would fire at 0 degrees in the well. If another circumferential direction is desired, however, charge holder 226 may be incrementally adjusted in certain embodiments or infinitely adjusted in other embodiments to any position between the locations of maximum travel which have been described above as approximately 60 degrees from vertical in either direction in the illustrated embodiment. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0056] Referring next to figures 10A-10C, therein are depicted various views of an apparatus for dynamically adjusting the center of gravity of a perforating apparatus of the present invention that is generally designated 240. Apparatus 240 includes a charge holder depicted as a charge tube 242 that is rotatably mounted in a gun carrier in a manner described above via bearings 244, as best seen in figures 10A and 10C. Charge tube 242 supports a plurality of shaped charges 246. Apparatus 240 also includes a dynamically adjustable weight system depicted as weight tube 250, as best seen in figures 10B and 10C. Weight tube 250 is formed from a partially tubular member. Weight tube 250 is rotatable mounted within a swivel member 252 that is mounted within charge tube 242 such that weight tube 250 may be rotated about 120 degrees circumferentially within charge tube 242. One or more coupling members depicted as pins 254 are used to selectively prevent rotation of weight tube 250 relative to swivel member 252. In operation, the dynamically adjustable weight system of apparatus 240 allows field personnel to make dynamic adjustments in the center of gravity of a perforating apparatus in the field. This ability provides the versatility to make adjustments to apparatus 240 that will not only allow the field personnel to shoot in a desired direction but also prevent shooting in an undesired direction, such as in the direction of a control line or other hazard disposed to the exterior of the casing string or within the casing string. Specifically, in the illustrated embodiment, this is accomplished by selectively releasing the connection, such as pins 254, between weight tube 250 and swivel member 252 then rotating weight tube 250 relative to swivel member 252 such that weight tube 250 is positioned in the desired orientation relative to shaped charges 246. For example, if weight tube 250 was installed relative to shaped charges 246 as shown in figures 10B-10C and deployed in a

horizontal well, weight tube 250 would cause charge tube 242 to rotate to the position depicted in figures 10B-10C wherein shaped charges 246 would fire at 0 degrees in the well. If another circumferential direction is desired, however, weight tube 250 may be incrementally adjusted in certain embodiments or infinitely adjusted in other embodiments to
5 any position between the locations of maximum travel which have been described above as approximately 60 degrees from vertical in either direction in the illustrated embodiment. Accordingly, the directions the shaped charges will perforate the well may be dynamically adjusted by field personnel after the location of any wellbore hazards has been determined.

[0057] While this invention has been described with reference to illustrative embodiments,
10 this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention will be apparent to persons skilled in the art upon reference to the description. It is, therefore, intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A perforating apparatus used to perforate a subterranean well, the perforating apparatus comprising:

a generally tubular gun carrier;

5 a charge holder rotatably mounted within the gun carrier;

at least one shaped charge mounted in the charge holder and operable to perforate the well upon detonation; and

a dynamically adjustable weight system operably associated with the charge holder, the dynamically adjustable weight system operable to adjust the center of gravity of the charge holder such that gravity will cause the charge holder to rotate within the gun carrier to
10 position the at least one shaped charge in a desired circumferential direction relative to the well prior to perforating.

2. The perforating apparatus as recited in claim 1 wherein the dynamically
15 adjustable weight system further comprises a plurality of discrete weights that are individually coupled to the charge holder at a plurality of longitudinal locations.

3. The perforating apparatus as recited in claim 2 wherein, for each of the longitudinal locations, the charge holder includes a plurality of circumferentially distributed
20 openings.

4. The perforating apparatus as recited in claim 3 wherein the circumferentially distributed openings are uniformly distributed at between about 15 and about 60 degree increments.
25

5. The perforating apparatus as recited in claim 2 wherein, for each of the longitudinal locations, the charge holder includes a circumferentially extending slot.

6. The perforating apparatus as recited in claim 5 wherein the slots extend
30 circumferentially between about 90 and 180 degrees.

7. The perforating apparatus as recited in claim 1 wherein the dynamically adjustable weight system further comprises a plurality of longitudinally extending tubes operable to contain a weighted material therein.

8. The perforating apparatus as recited in claim 1 wherein the dynamically adjustable weight system further comprises weights formed from a malleable material.

9. The perforating apparatus as recited in claim 1 wherein the dynamically adjustable weight system further comprises a weight tube that is rotatable relative to the charger holder.

10. The perforating apparatus as recited in claim 1 wherein the at least one shaped charge further comprises a plurality of shaped charges and wherein each of the shaped charges is positioned in the charge holder to fire in substantially the same circumferential direction.

11. The perforating apparatus as recited in claim 1 wherein the at least one shaped charge further comprises a plurality of shaped charges and wherein the shaped charges are positioned in the charge holder to fire in multiple circumferential directions.

12. A perforating apparatus used to perforate a subterranean well, the perforating apparatus comprising:

a generally tubular gun carrier;

5 a charge tube rotatably mounted within the gun carrier, the charge tube including a plurality of circumferentially extending slots;

at least one shaped charge mounted in the charge tube and operable to perforate the well upon detonation; and

10 a dynamically adjustable weight system coupled to the charge tube, the dynamically adjustable weight system including a plurality of discrete weights that are coupled to the charge tube at the slots, such that the circumferential location of the weights is adjustable along the length of the slots to adjust the center of gravity of the charge tube such that gravity will cause the charge tube to rotate within the gun carrier to position the at least one shaped charge in a desired circumferential direction relative to the well prior to perforating.

15 13. The perforating apparatus as recited in claim 12 wherein the slots extend circumferentially between about 90 and 180 degrees.

14. The perforating apparatus as recited in claim 12 wherein adjacent slots extend in circumferentially opposite directions.

20

15. The perforating apparatus as recited in claim 12 wherein the weights are attached to the charge tube using bolts that are selectively slidable within the slots.

25 16. The perforating apparatus as recited in claim 12 wherein the at least one shaped charge further comprises a plurality of shaped charges and wherein each of the shaped charges is positioned in the charge holder to fire in substantially the same circumferential direction.

30 17. The perforating apparatus as recited in claim 12 wherein the at least one shaped charge further comprises a plurality of shaped charges and wherein the shaped charges are positioned in the charge holder to fire in multiple circumferential directions.

18. A method of perforating a subterranean well comprising the steps of:
identifying at least one undesired circumferential direction associated with a
perforating interval in the well;
adjusting components of a dynamically adjustable weight system to change the center
5 of gravity of a charge holder rotatably mounted within a gun carrier;
positioning the gun carrier within the perforating interval in the well;
gravitationally aligning at least one shaped charge mounted in the charge holder in at
least one desired circumferential direction relative to the well that does not correspond with
the at least one undesired circumferential direction; and
10 firing the at least one shaped charge to perforate the well in the at least one desired
circumferential direction.

19. The method as recited in claim 18 wherein adjusting components of a
dynamically adjustable weight system further comprises relocating discrete weights
15 circumferentially about the charge holder.

20. The method as recited in claim 19 wherein relocating discrete weights
circumferentially about the charge holder further comprises relocating the discrete weights
relative to circumferentially distributed openings in the charge holder.

20

21. The method as recited in claim 19 wherein relocating discrete weights
circumferentially about the charge holder further comprises relocating the discrete weights
relative to circumferentially extending slots in the charge holder.

22. The method as recited in claim 18 wherein adjusting components of a
dynamically adjustable weight system further comprises changing the amount of weighted
material in at least one longitudinally extending tube.

25

23. The method as recited in claim 18 wherein adjusting components of a
dynamically adjustable weight system further comprises reshaping malleable material
30 disposed within the charge holder.

30

24. The method as recited in claim 18 wherein adjusting components of a dynamically adjustable weight system further comprises rotating a weight tube relative to the charge holder.

5 25. The method as recited in claim 18 wherein firing the at least one shaped charge to perforate the well in the at least one desired circumferential direction further comprises firing a plurality of shaped charges in substantially the same circumferential direction.

10 26. The method as recited in claim 18 wherein firing the at least one shaped charge to perforate the well in the at least one desired circumferential direction further comprises firing a plurality of shaped charges in multiple circumferential directions.

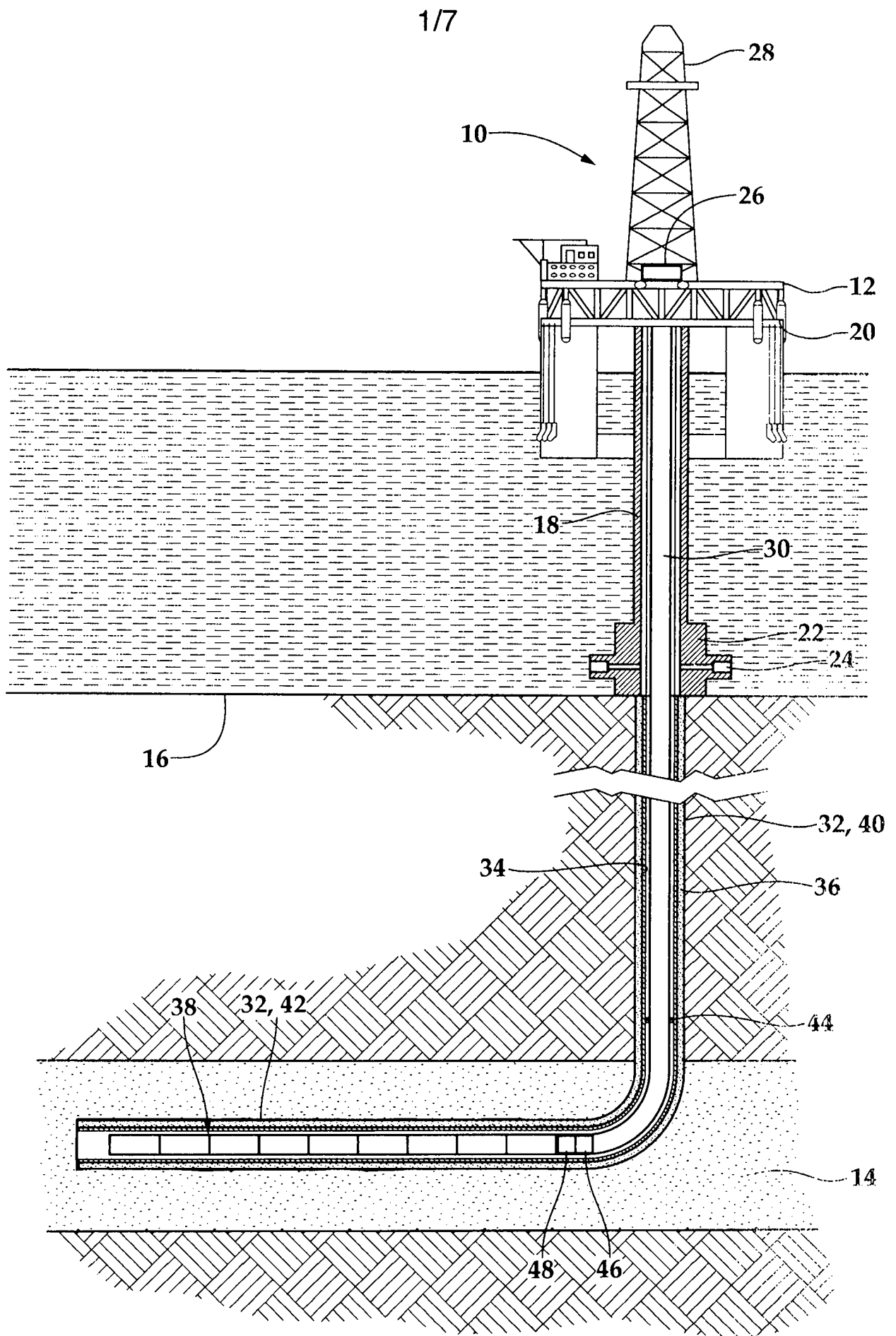
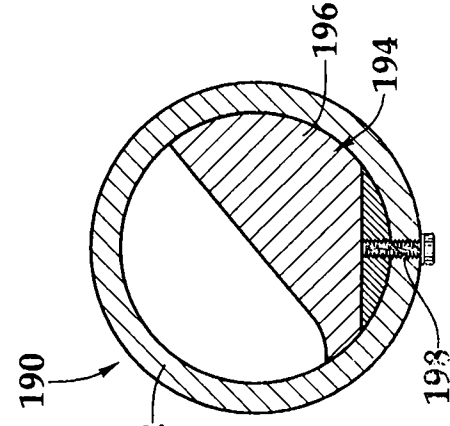
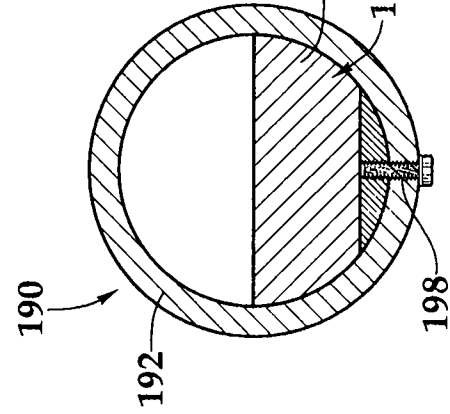
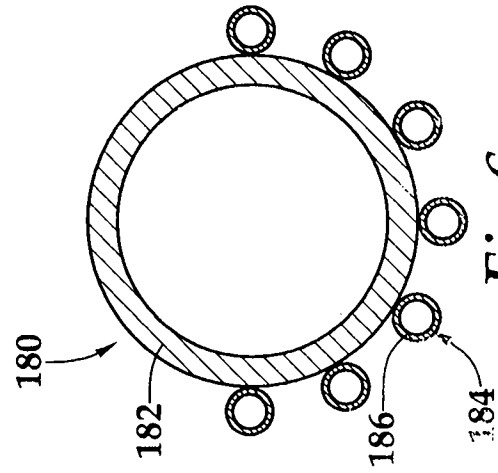
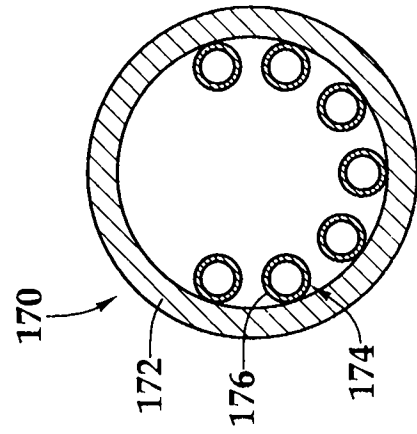
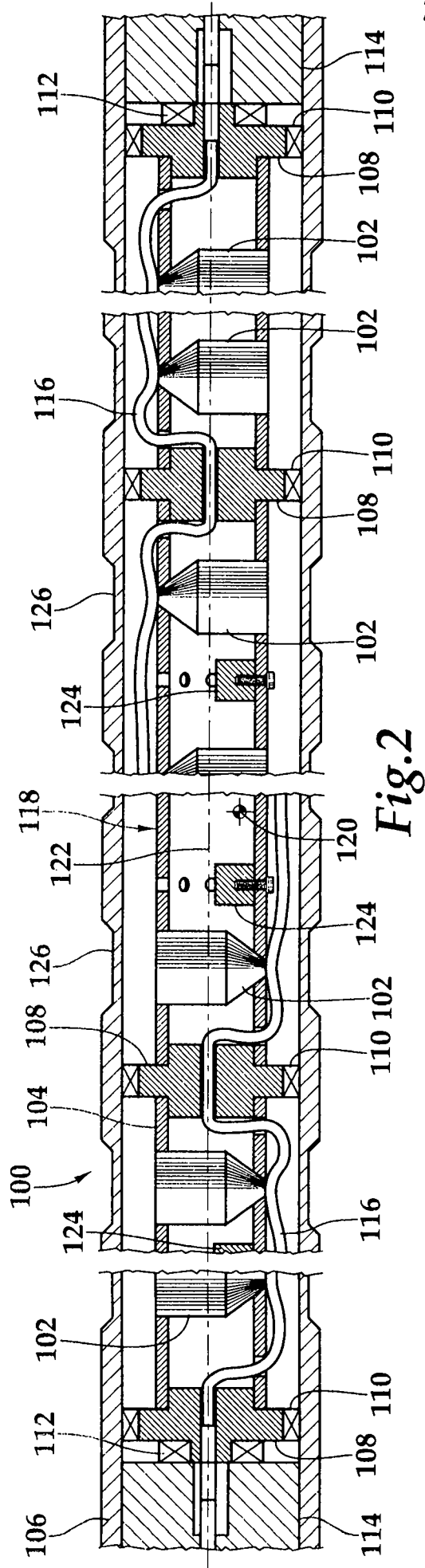


Fig.1



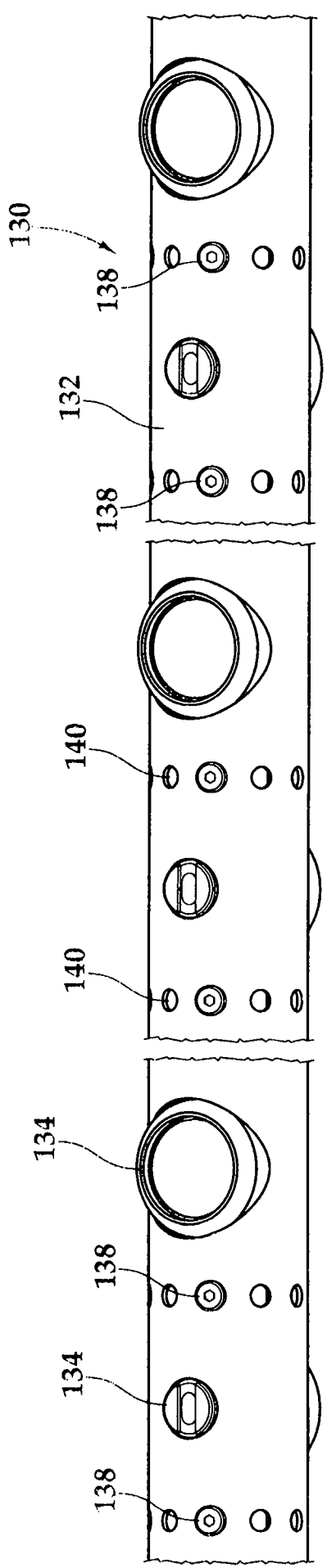


Fig. 3A

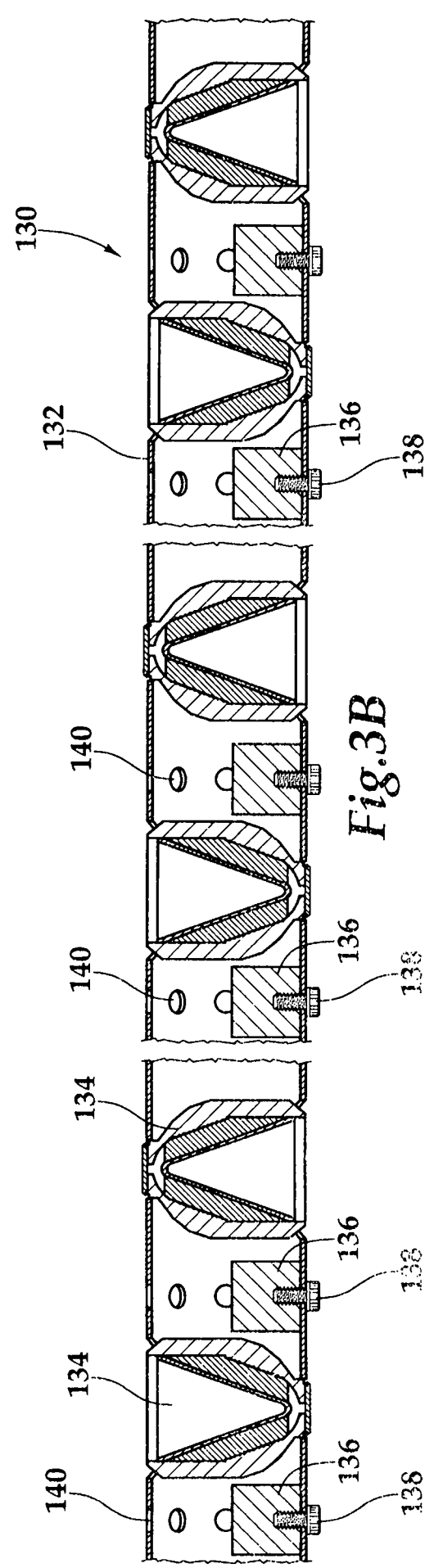


Fig. 3B



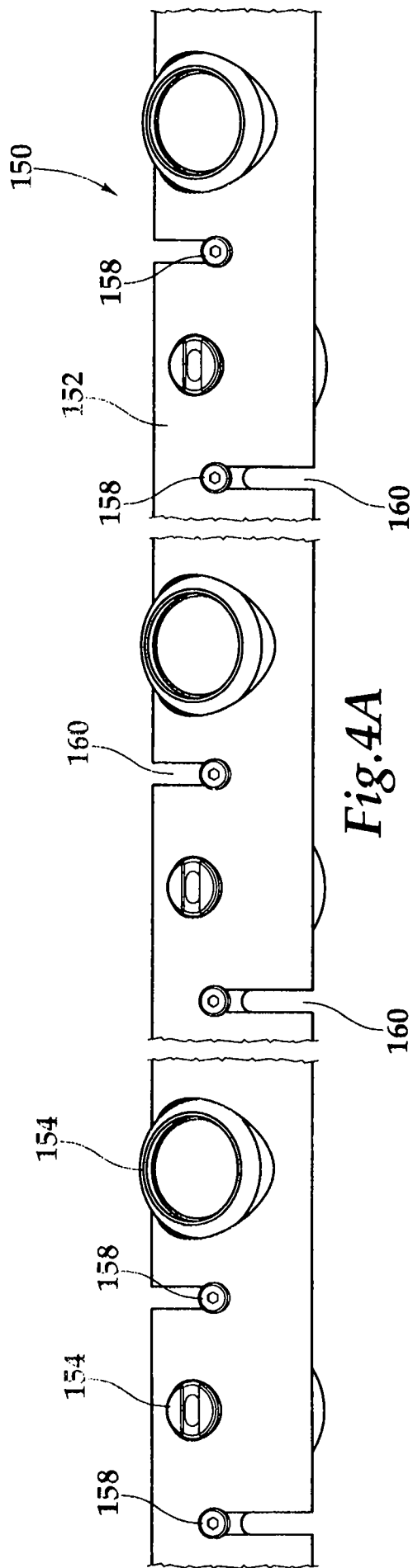


Fig. 4A

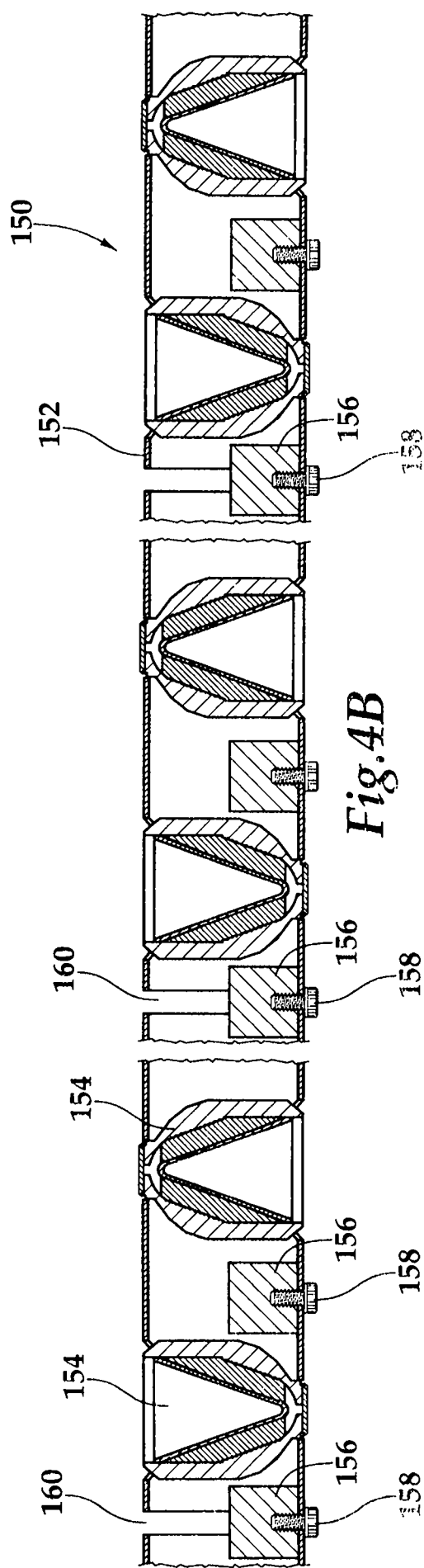


Fig. 4B



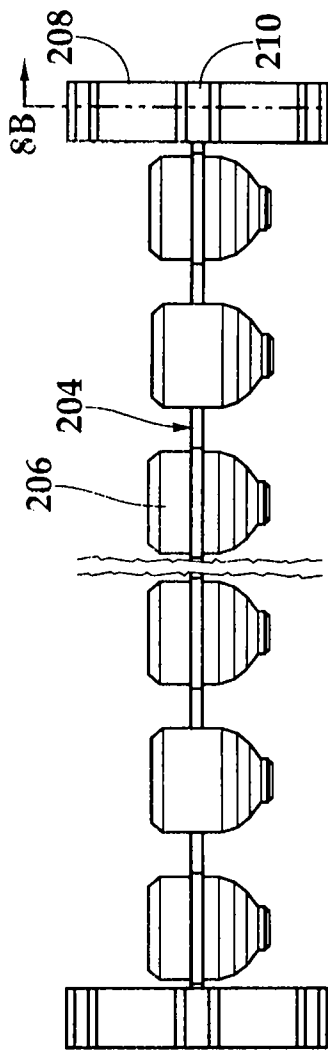


Fig. 8A

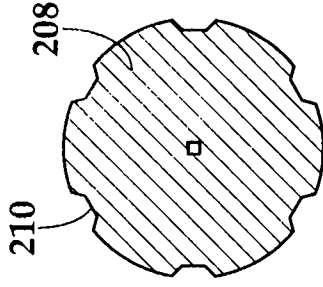


Fig. 8B

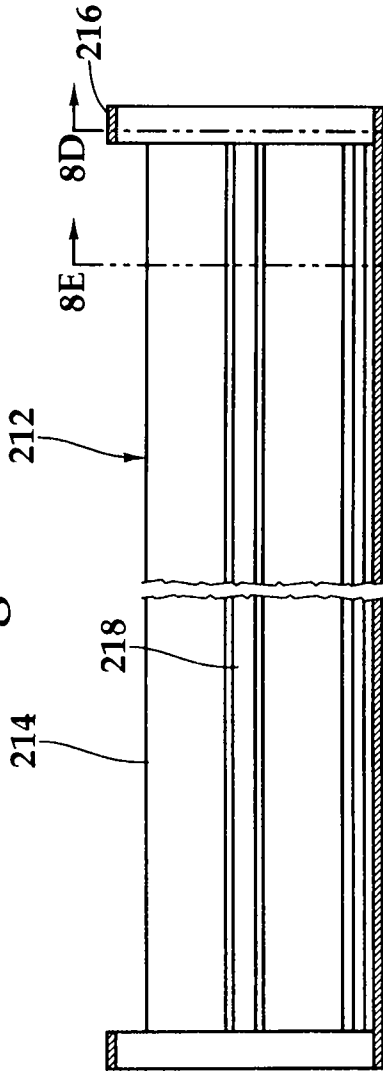


Fig. 8C

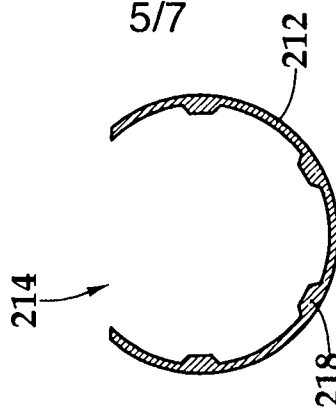


Fig. 8E

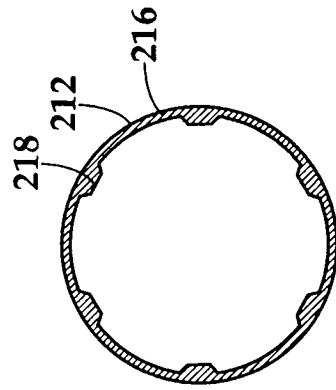


Fig. 8D

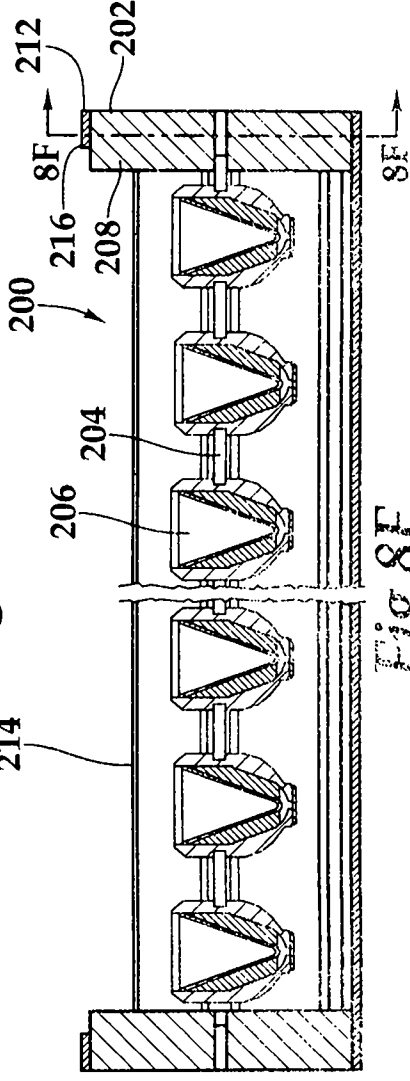


Fig. 8F

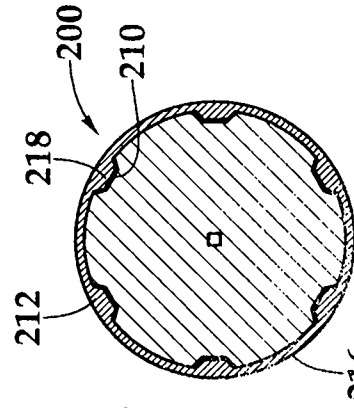
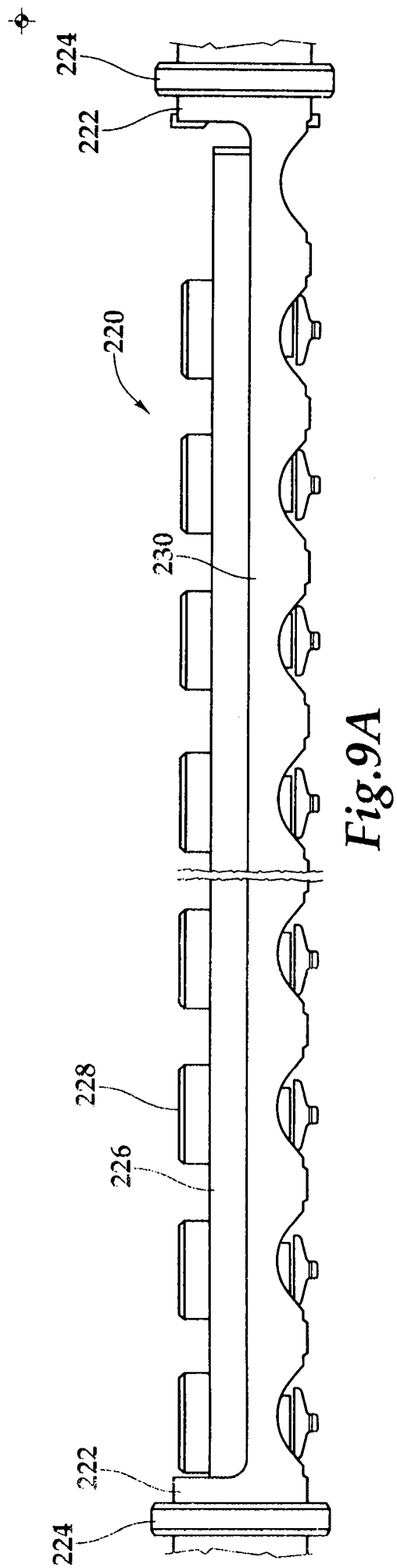
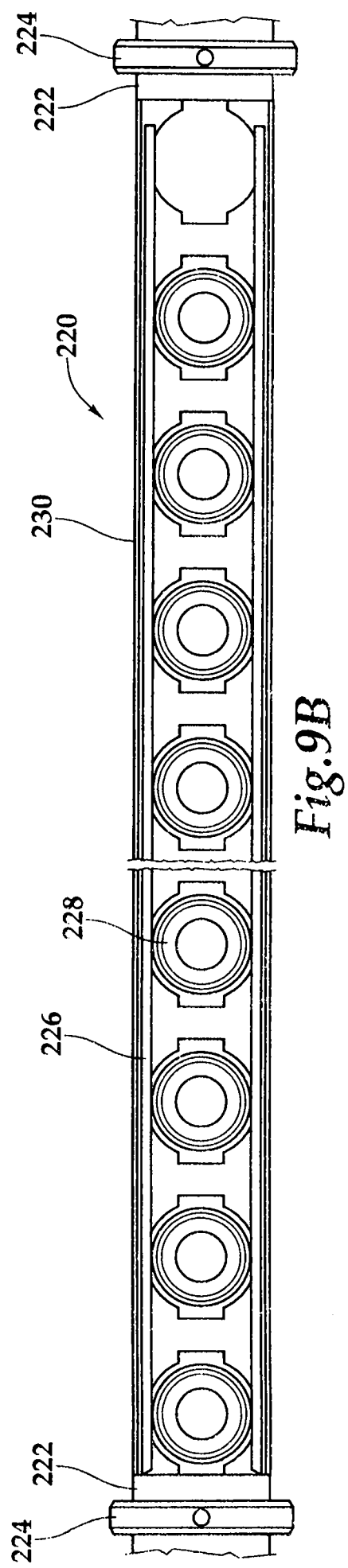


Fig. 8G





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No. 11-134831- -00000-0000

PATENTE DE INVENCION ☐

MODEL

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Act. 411 PRESENTACION Folios: 113

- ☐ Indicación que se solicita una patente.
 - ☐ Datos de identificación del solicitante o de la persona que presenta la solicitud
 - ☐ Descripción de la invención
 - ☐ Dibujos de ser estos pertinentes
 - ☐ Comprobante de pago de las tasas establecidas (De ser el caso formato de descuento)
- Completa ☐ Incompleta ☐

PATENTE DE INVENCION PCT ☒ MODELO DE UTILIDAD PCT ☐ Art.33 Decisión 486/00, Circular Única

- ☒ Indicación que se solicita una PCT
 - ☒ Copia de la solicitud en español, tal como fue presentada inicialmente (capítulo descriptivo, reivindicatorio, resumen)
 - ☒ Dibujos de ser estos pertinentes
 - ☒ Comprobante de pago de las tasas establecidas (de ser el caso formato de descuento)
- Completa ☒ Incompleta ☐

DISEÑO INDUSTRIAL ☐

(Art. 119 Decisión 486/00)

- ☐ Indicación que se solicita Diseño industrial
 - ☐ Datos de identificación del solicitante o de la persona que presenta la solicitud
 - ☐ Representación gráfica y fotográfica del Diseño industrial o muestra del material que incorpora el diseño
 - ☐ Comprobante de pago de las tasas establecidas
- Completa ☐ Incompleta ☐

ESQUEMA DE TRAZADO ☐

(Art. 92 Decisión 486/00)

- ☐ Indicación que se solicita un esquema de trazado
 - ☐ Datos de identificación del solicitante o de la persona que presenta la solicitud
 - ☐ Representación gráfica de un esquema de trazado
 - ☐ Comprobante de pago de las tasas establecidas
- Completa ☐ Incompleta ☐

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